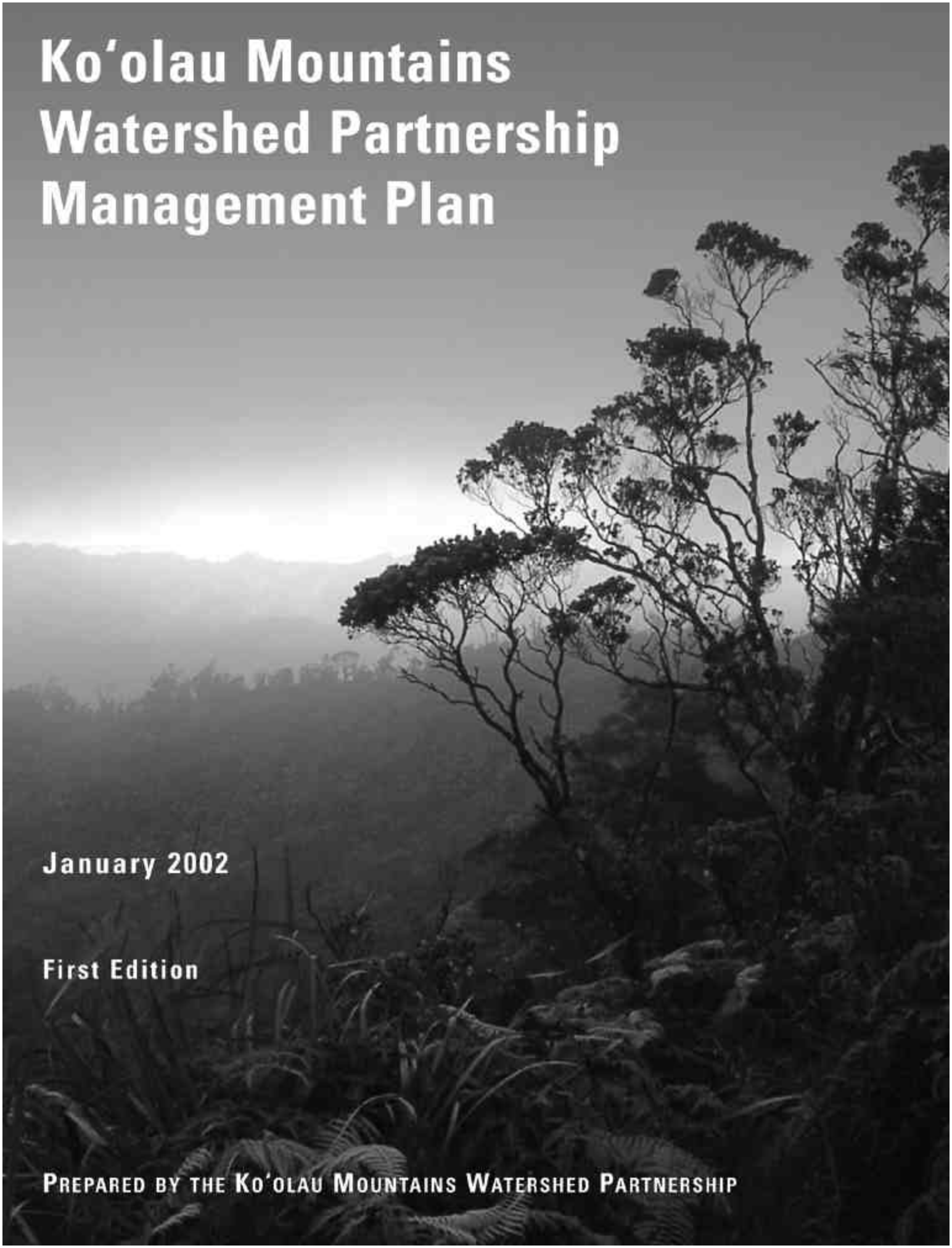
Ko'olau Mountains Watershed Partnership Management Plan



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Prepared by the Ko'olau Mountains Watershed Partnership

KO‘OLAU MOUNTAINS WATERSHED PARTNERSHIP MANAGEMENT PLAN

Prepared by Jason Sumiye for
The Ko‘olau Mountains Watershed Partnership

Bishop Museum
Dole Food Company, Inc.
City and County of Honolulu Board of Water Supply
Kamehameha Schools
Manana Valley Farm, LLC
Queen Emma Foundation
State of Hawai‘i Agribusiness Development Corporation
State of Hawai‘i Department of Hawaiian Home Lands
State of Hawai‘i Department of Land and Natural Resources
Tiana Partners, et al.
U.S. Army
U.S. Fish and Wildlife Service

Associate Partners:
State of Hawai‘i Department of Health
The Nature Conservancy of Hawai‘i
U.S. Environmental Protection Agency
U.S. Forest Service
U.S. Natural Resources Conservation Service
U.S. Geological Survey

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Koʻolau Mountains Watershed Partnership Management Plan

Executive Summary

Early Polynesian settlers recognized the intimate relationship between Hawaii's forested watersheds and its dependable supply of clean water. This relationship is still relevant today, as these forested watersheds efficiently recharge Hawaii's vital underground aquifers, while also providing a good habitat for flora and fauna and recreational opportunities for island residents and visitors alike. Our island's forested watersheds temper the erosive effects of rain, prevent soil from washing into the ocean, increase infiltration rates into the soil, and condense moisture from the clouds.

The Koʻolau Mountains Watershed Partnership ("KMWP") has always recognized the importance of developing a management plan. It has been one of its primary objectives since its inception in August 1999. Work toward this objective was initiated with the preparation of a KMWP Preliminary Assessment Plan in June 2000. The plan is modeled on the foundations of its state predecessors – the East and West Maui Mountains Watershed Management Plans. The development of the KMWP management plan however, has been a pioneering endeavor, as the Koʻolau Mountains' biophysical and sociocultural context is unique unto itself.

Just as native forested watersheds exist in a delicate ecological balance, the use of balance has been an important strategy through the writing process of this plan. Since this management plan encompasses a massive land area of almost 100,000 acres and spans the entire eastern side of the Oʻahu, detailed plans of all areas were impractical. Lack of any specificity though, would reduce the utility of the plan. Therefore there has been a conscious effort to strike a balance between the landscape and community perspectives, at times overviewing resources across the entire watershed area, and at other moments highlighting specific areas for management activities.

This plan is an attempt to balance the varied interests represented by each of KMWP's unique members. Under the overarching umbrella of watershed management, each member brings special interests and technical niches. While this plan was written in rather general terms to incorporate a wide range of potential activities, care was also taken to ensure that this plan maintained focus and direction. Many watershed plans simply become amalgamations of potential actions rather than a strategy for actions. In an effort to avoid becoming a diluted management wish list, this management plan concludes with a 2002-2003 action plan, maintaining KMWP's founding goals and objectives as the guiding beacon to delineate clear priorities and projects for the partnership's nascent stages.

The management plan sought to balance perspectives of the plan as a "process" versus a "product". This management plan, like the watershed that it describes, is an organic product that will evolve and change, as there are still significant data gaps, and natural

resource management activities and priorities can be subject to rapid change. The plan should therefore be regarded as the beginning of the implementation process rather than an end with a planning product. It serves as a snapshot in 2002 and a foundation for future updates. Since the KMWP is in its infancy however, it is important that this plan be substantive enough to serve as a launching pad for action, allowing KMWP to proceed with implementation of the plan for at least the first few years. Imperfect knowledge is a reality in watershed management, given the complexity of ecological patterns, large land area involved, and long term for management (Ringgold, et al., 1996). Management must occur in the face of uncertainty; in fact, good management will draw on that uncertainty through an adaptive management scheme to design a flexible approach toward managing the watershed.

The initial step in developing a watershed management plan is to gain an understanding of the resources within the watershed. In **Chapter II** the management plan details all of the Ko‘olau Mountains Watershed Area’s known resources, both biophysical and sociocultural, and evaluates the current condition of these resources. A comprehensive overview at the watershed scale is useful to provide needed perspective to determine which particular resource elements warrant the KMWP’s protection and management investment. **Chapter III** outlines the extent and severity of the threats to these watershed’s resources in order to get a better idea of the primary management challenges. These primary threats include invasive non-native plant species, feral ungulates and other non-native animals, human activities, aquatic pollutants and wildfire. **Chapter IV** conducts an overview of existing management programs, as ongoing management will serve as a building block for future management activities. This chapter also functions as a tool to assist partners in understanding the strengths, directives, experiences and potential contributions from individual member organizations of KMWP. **Chapter V** outlines the management priorities and planning needs for the KMWP. These encompass the areas of threat management, water resources and watershed management, biodiversity protection, cultural resources management, education awareness and public outreach and administrative coordination. **Chapter VI** highlights some important survey needs and outlines indicators that may be used to gauge the success of the management programs described in Chapter V. **Chapter VII** contains an action plan for years 2002-2003 with priority strategies, tasks taken from projects listed in Chapter V, along with cost estimates for these projects.

The management plan concludes with a summary, a list of references, and several appendices that will be of value for management purposes. Maps, providing a snapshot of certain resources on the landscape, are referenced throughout the text and compiled in Appendix A. A special feature of this management plan are the Map Overlays (labeled A-E), which are located in the back pocket of the management plan, and can be applied in any combination over the base maps to gain a more integrated view of the watershed area. Additionally, although not included or formally presented

in the management plan, the Geographic Information System (GIS) project files and database that were used to create these static map images are an integral component of management. As the base of knowledge and information continues to grow, the predictive power and management utility of the GIS database system will correspondingly increase in value.

Acronyms and Abbreviations

ADC	Agribusiness Development Cooperation
BM	Bishop Museum
BMP	Best Management Practices
BWS	Board of Water Supply, City and County of Honolulu
CCC	Civilian Conservation Corps
CGAPS	Coordinating Group on Alien Pest Species
CWB	Clean Water Branch
CWRM	Commission on Water Resource Management
DAR	Division of Aquatic Resources
DHHL	Department of Hawaiian Home Lands
DLNR	Department of Land and Natural Resources
DoFAW	Department of Forestry and Wildlife
DOH	Hawai‘i State Department of Health
EPA	United States Environmental Protection Agency
FHS	Friends of Ha‘ikū Stairs
FLIR	Forward-Looking Infrared
GIS	Geographic Information Systems
GWPP	Groundwater Protection Program
HEAR	Hawai‘i Ecosystems at Risk
HECO	Hawaiian Electric Co.
HINHP	Hawai‘i Natural Heritage Program
HPC	Hawai‘i County Planning Commission
HSBP	Hawaiian Stream Bioassessment Protocol
INRMP	Integrated Natural Resources Management Plan
IPM	Integrated Pest Management
KLOA	Kawailoa Training Area
KMWP	Ko‘olau Mountains Watershed Partnership
KTA	Kahuku Training Area
MOU	Memorandum of Understanding
MVF	Manana Valley Farm, LLC
NAR(S)	Natural Area Reserve (System)
NAWQA	National Water Quality Assessment
NIS	Non-indigenous Invasive Species
NPV	Net Present Value
NRCS	National Resources Conservation Service
OISC	O‘ahu Invasive Species Committee
PASH	Public Access Shoreline Hawai‘i
PBIN	Pacific Basin Information Node
PCSU	Pacific Cooperative Study Unit
PHA	Public Hunting Area
PIERC	Pacific Island Ecosystems Research Center
PRC	Polluted Runoff Control Program
QEF	Queen Emma Foundation
SBMR	Schofield Barracks Military Reservation
SHPD	State Historic Preservation Division
SPD	State Parks Division
TMDL	Total Daily Maximum Load
USFS	U. S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VSN	Volunteer Stewardship Network

I. Introduction

On the island of O‘ahu, the Ko‘olau Mountain Range is a vital natural resource, a place where the winds, land, plants and water converge in a symphony of natural beauty and the interdependency of these elements runs deep. The critical role played by Hawaii’s forests in supporting water has long been recognized. In 1902 U.S. Forester E.M. Griffith wrote, “Forest protection means not only increasing the rainfall, but more important still, conserving the water supply. The future welfare and agricultural prosperity of the Hawaiian Islands depends upon the preservation of the forest.” While the relative importance of agriculture to Hawaii’s economy has declined in the last 100 years, the salience of these words has not. The forests continue to furnish a host of benefits: economic stability, social well-being, environmental health, recreational opportunities and habitat for endangered species, in addition to being the major source of water for O‘ahu. All forested areas help protect the watershed, but Oahu’s native forests, in particular, have evolved into efficient ecosystems to capture and store water. The forested areas of the Ko‘olau Mountains are vital for recharge of Oahu’s underground aquifers and a dependable source of water for its streams. Fresh water is not an infinite resource, and its high quality and quantity are fundamentally linked to the sustainability of our forested watersheds.

The goal of the KMWP is to protect these forested watershed areas within the Ko‘olau Range. Efforts to protect these vital watershed values began to coalesce on August 4, 1999, when a group of both government and private landowners signed a Memorandum of Understanding, officially forming the Ko‘olau Mountains Watershed Partnership (KMWP). These eight original signatories, whose holdings comprised approximately 80% of the total acreage within the Ko‘olau watershed, were:

- Bishop Museum
- City and County of Honolulu (Board of Water Supply)
- Kamehameha Schools
- Queen Emma Foundation
- State of Hawai‘i Agribusiness Development Corporation
- State of Hawai‘i Department of Hawaiian Home Lands
- State of Hawai‘i Department of Land and Natural Resources
- U.S. Army

Subsequently, on November 19, 1999, Manana Valley Farm, LLC, Tiana Partners, et al., and Dole Food Company, Inc. signed on as active partners. Most recently, the U.S. Fish and Wildlife Service joined the alliance following the acquisition of the O‘ahu Forest National Wildlife Refuge in December 2000. Although it is acknowledged that each of these landowners may have different priorities, mandates and constituencies, they all share a common commitment to the protection of the Ko‘olau Mountains Watershed.

Although KMWP membership is limited to landowners, other agencies are supporting the KMWP in principle, and have stepped forward to assist KMWP because of their institutional mission. These associates include:

- State of Hawai‘i Department of Health
- The Nature Conservancy of Hawai‘i
- U.S. Environmental Protection Agency
- U.S. Forest Service
- U.S. Geological Survey
- U.S. Natural Resources Conservation Service

Over the last decade watershed-based initiatives have dramatically proliferated as a primary conservation mechanism in the United States (Born and Genskow, 2001, Kenney, 1999), as pundits throughout the world have reached wide agreement that the watershed is the most appropriate unit for water management (Heathcote, 1998). Watershed approaches have now been adopted as a fundamental principle of the Federal Clean Water Action Plan (1998) and are supported by the Environmental Protection Agency, the U.S. Department of Agriculture, and other federal agencies. Hawai‘i has been at the forefront of this trend, as successful watershed partnerships have been created in East Maui, West Maui, East Moloka‘i, and Lāna‘i, and are forming on Kaua‘i and Kohala, infusing a cooperative spirit between public and private sectors.

Even with a growth in watershed partnerships, the Ko‘olau Mountains remain a unique entity in Hawai‘i. Spanning nearly 100,000 acres, with an estimated sustained yield of over 133 billion gallons of water each year, the forested *mauka,* or mountainous areas of the watershed are critical for maintaining the continued flow and recharge of water to support the burgeoning population of 880,000 residents on O‘ahu. In addition to the utility of the water, the watershed has been found to have a multitude of other values as well. Accounting for such amenities as ground water quantity, water quality, in-stream uses, species habitat, biodiversity, subsistence, native Hawaiian gathering rights, hunting, aesthetics, commercial harvests, ecotourism, and climate control, a team of economists at the University of Hawai‘i conducted a natural resource valuation of the Ko‘olau Mountains watershed. Their preliminary economic analysis of the amenities provided by the Ko‘olau Mountains watershed shows an estimated Net Present Value (NPV) of $7.44 billion to $14 billion (Roumasset, et al., 1997), clearly reaffirming the value of the watershed and KMWP’s efforts toward its protection.[1] With such great interests at stake and the enormous value of the water supply, forest protection in the Ko‘olau Range is clearly a high priority for the entire state.

This cooperative, integrated management approach has been deemed the best approach to manage large, forested watersheds in Hawai‘i for several reasons:

- CONNECTIVITY: In a watershed, each area is affected by the health of the neighboring parcels. The health of the watershed area cannot be maintained without the involvement of all major landowners in the Ko‘olau watershed area.
- SHARING: Individually, the resources of each watershed partner are limited. Collaboratively, the partners can take advantage of economies of scale for large

[1] NPV per acre was estimated at $76,000 to $143,535, with mean annual benefits at roughly $165 million or $1,700 per acre.

projects such as fencing or other infrastructure needs. KMWP also provides a venue to promote the exchange of technical expertise to make each partner more effective.

- REGIONAL THREATS: The management challenges that threaten the health of the watershed, such as feral animals and alien weeds are regional in scope, and are not restricted by property boundaries. By working together and employing a systems approach to these issues, the KMWP will be more effective in controlling these threats.

Key Management Goals and Objectives

The KMWP's Memorandum of Understanding (MOU) established the foundation for active, cooperative management activities between participating partners within the Koʻolau watershed. The MOU recognizes that a healthy forested Koʻolau watershed is vital to sustain the future quality and quantity of Oahu's water supply, and that the management of these forests also benefits Hawaii's native flora and fauna. Within the MOU, the partners agree to work together to formulate watershed projects for the *mauka* regions of the Koʻolau mountains and join in cooperative efforts to seek funds for these projects. These proactive joint-management projects will address trans-boundary threats to the watershed such as feral ungulates, invasive non-native plants, insects, disease, fire, and in some instances, human impacts.

The Memorandum of Understanding is the basis for the ultimate goal of the KMWP, which is to maintain a healthy watershed as a reliable source of high quality water for Oahu's people. It is of particular importance because it represents the common ground for all partners. All goals and project activities will seek to reflect and evoke this commonality, with the forests of the Koʻolau Range serving as the focal point of KMWP's management. The forests sustain water recharge capacity, reduce the rain's erosive effects, condense moisture from the clouds, and deliver a consistent and dependable source of artesian and surface water. KMWP aims to show improvements in water and environmental quality by enabling comprehensive and sustainable watershed management projects that address the threats to the watershed, while maintaining its integrity and protecting its economic, sociocultural and ecological resources.

This management plan will be the primary tool used to outline the resources and values of the watershed and direct the activities of KMWP to protect these resources. It will first characterize the current condition of the watershed, describing both the biophysical and sociocultural resources found within the watershed area. It will then highlight the threats to these resources, and summarize any management activities that are currently being conducted to address these threats. Based on this information, the management plan will prescribe priority management activities and accent planning needs, if necessary. The environmental impacts of these activities will be considered, followed by a suggested protocol to monitor these recommended activities. Through this process, the actions necessary to protect the water resources in the Koʻolau Mountains will be developed and implemented.

II. Description and Current Condition of the Ko‘olau Mountains Watershed

The initial step in developing a watershed management plan is to gain an understanding of those resources within the watershed that warrant protection and management. This section delineates those resources, both biophysical and sociocultural, and evaluates their current condition within the Ko’olau Mountains Watershed Area.

A. Biophysical Resources

1. Project Area, Location, Topography, Climate, Geology and Soil Types

The area delineated for management by the Ko‘olau Mountains Watershed Partnership spans across the entire Eastern side of O‘ahu and covers nearly 100,000 acres. The perimeter of the KMWP area is demarcated by the old forest reserve boundary, which was first established in the early 1900s when large private landowners along with the territorial government of Hawai‘i decided that the best way to protect the *mauka* lands was to fence the area, control feral animals, plant trees, and moderate development of these areas. For KMWP purposes, it was determined that the old forest reserve boundary be a logical designation for the Ko‘olau Mountains Watershed (See **Map#1: General Location**). While KMWP realizes that an *ahupua‘a* or “mountains to the sea” perspective is critical for the overall success of watershed management in Hawai‘i, it is focused on “doing its part” by maintaining the health and integrity of the forested *wao,* or inland areas of the watershed. As many wells, streams, and other water sources are located in and impacted by many areas outside KMWP boundaries, KMWP understands the importance of conducting management activities in all sections of the greater Ko‘olau watershed.

The land formations on a watershed are important to watershed management because they largely determine the rate by which water flows over the land and in turn influence the rate of groundwater infiltration. The highest point of the Ko‘olau Range is the summit of Kōnāhuanui at 3150 feet. Most of the area is mountainous and has been deeply dissected by erosion. The windward and leeward slopes of the Ko‘olau Mountains reveal drastic differences: the windward slopes of the Range are characterized by steep cliffs and short ridges less than four miles long, while the leeward side features parallel ridges as long as eleven miles, bounded by steep-sided stream valleys. The relatively gradual slope on the leeward side allows streams to meander and pass over rubble – producing higher infiltration rates. In contrast, the steep gradients and small drainage areas of the windward slopes tend to lead to rapid runoff and lower infiltration (Nichols, et al., 1996).

Soil type is also an important component of watershed systems. The nature of the underlying rock of a watershed is an important factor in defining the character of overlying soils. The soil types in Hawai‘i generally have a high clay content and are highly permeable; but once these clay soils are compacted they can quickly form an impenetrable layer. Since the majority of the KMWP area is comprised of rough mountainous land or cliff faces, it has not

been classified in terms of soils. There are two major exceptions. A large area of the northern edge of the KMW area is comprised of the Kapa‘a series, an Oxisol, or a highly weathered soil, rich in iron and aluminum oxide minerals. This soil is well drained, with slow to very rapid runoff and moderately rapid permeability. Also classified in terms of soils are the areas beneath the windward cliffs and the flat areas along the peaks of Kōnāhuanui (Pali Highway) and Lanihuli/Keahiakahoe (Likelike Highway). These contain the Waikane and I‘oleka‘a soil series, which are relatively infertile acidic Ultisol soils that form under forest vegetation from basic volcanic rock. The soils of these series are very deep and well drained, with moderately rapid permeability and slow to very rapid runoff, depending on slope.

2. Hydrology and Water Resources

The Ko‘olau Mountains are of paramount importance, supplying and protecting a large portion of Oahu’s water resources. This section will address four topics: 1) climate and rainfall, 2) groundwater resources, 3) surface water resources and, 4) water supply and consumption. The water cycle begins with rainfall, which during normal years averages about two billion gallons of rain per day on O‘ahu. Because volcanic rock is porous, much of this rain is naturally filtered through the soils of the Ko‘olau Range, slowly percolating its way down through volcanic rock to large underground formations called aquifers. Of course, not all of the rainfall makes its way into aquifers. Stream flow, runoff, withdrawals (from wells, shafts, and springs), evapotranspiration, and outflow to the ocean account for some of the water discharge. In southern and north-central O‘ahu, nearly equal amounts of the precipitation (42-43%) end up as recharge and evapotranspiration, with the remaining 15% accounted for by runoff. In southeastern O‘ahu, drier conditions lead to higher evapotranspiration rates, while on the windward side, steep slopes lead to higher runoff rates compared to the rest of the island. Table 1 displays USGS water budget estimates for different regions of O‘ahu. [2]

Table 1: Predevelopment water budget, Island of O‘ahu (in millions of gallons per day)

Water-Budget Category	Southern O‘ahu		Southeastern O‘ahu		Windward O‘ahu		North-Central O‘ahu	
	in mgd	percent	in mgd	percent	in mgd	percent	in mgd	percent
Precipitation	842	-	62	-	536	-	434	-
Runoff	127	15%	7	11%	100	19%	65	15%
Evapotranspiration	356	42%	36	58%	239	45%	185	43%
Recharge	359	43%	19	31%	198	37%	184	42%

Source: Shade and Nichols, 1996

Climate and Rainfall

Mild temperatures, moderate humidity, prevailing northeasterly tradewinds, and extreme variation in rainfall over short distances characterize the climate on O‘ahu. In fact, there are

[2] Since these estimates may vary significantly, primarily with climatic zone, and there is significant scientific uncertainty about the hydrological process in the Ko‘olau Mountains, including incomplete soil surveys, rainfall and hydro-geological data, and evapotranspiration rates, these numbers should be interpreted as rough estimates (Giambelluca, 1983).

few places in the world where rainfall gradients are as steep as they are in Hawai‘i, resulting in a range from the wettest spot on earth at Mount Wai‘ale‘ale on Kaua‘i to extremely arid areas (Blumenstock and Price, 1967). In the Ko‘olau Mountains, the average annual rainfall is between 40 and 280 inches of rain per year, most of which is received at higher elevations along the entire crest of the range (Taliaferro, 1959). The highest rainfall is often recorded in the northern regions at the Kahana station during March and April, while the lowest amounts occur in the southern portions of the range. Generally, rainfall increases with elevation (See **Overlay A: Water Resources**). Intense rainfall from severe storms, coupled with the steep topography on the windward side of the Ko‘olau Mountains, increase the risk of flash floods to those areas.

In addition to rainfall, water finds its way into the Ko‘olau aquifers via fog drip and irrigation water that is not lost to runoff, soil storage or evapotranspiration. Fog-drip (moisture absorbed by vegetation from the clouds), may be a major source of water recharge in the hydrological cycle of the Ko‘olau Mountains. It is believed that evapotranspiration rates in the Ko‘olau Mountains’ upper reaches may be suppressed because its cool-weather, high-elevation forest is almost always receiving some form of moisture. [3]

Groundwater Resources

As the main source of fresh water on O‘ahu, groundwater recharge is a valuable product of the Ko‘olau forest, with a net present value of at least $1.42 billion to $2.63 billion (Roumasset, et al., 1997). The total mean annual recharge for the Ko‘olau rift zone groundwater area, which comes entirely from rainfall and fog condensation, accounted for approximately 369 million gallons per day, or 47% of the Oahu’s 791 million gallons per day (USGS, 1999). Oahu’s groundwater can be found in several forms, each directly related to the geologic formations on the island.

There are two major aquifers on O‘ahu: Wai‘anae and Ko‘olau. The Ko‘olau aquifer underlies the eastern three-quarters of the island and is the main source of water for southern O‘ahu and Honolulu (Shade and Nichols, 1996). Bordering the island along the southern and northern coastal areas are coastal-plain deposits known as caprock. These deposits include marine and terrestrial sediments, limestone and reef deposits. In southern and north central O‘ahu, the caprock confines the ground water in the underlying Ko‘olau Basalt basal aquifer. By impeding the discharge of ground water to the sea, the caprock allows a thick freshwater lens to build up beneath parts of the island. Along the coastal plains, this caprock forms artesian wells, which are wells with sufficient pressure to raise free flowing water above the land surface. One important aquifer in the Ko‘olau area is the Honolulu-Pearl Harbor area – the most productive on O‘ahu, capable of sustaining a production rate of 202 million gallons a day (mgd).[4] Preventing a mere 5% reduction of the Pearl Harbor aquifer translates into a potential benefit of over $560,000 per year (Gutrich and Donovan, 2001).

[3] Estimates suggest that the quantity of fog-drip for the leeward Ko‘olau slopes is about 6 inches per year for areas above the 2000 foot cloud base (Giambelluca, 1983).

[4] Of this 202 million gallons per day, 104 come from the Waipahu-Waiawa aquifer, 45 from Waimalu, and 53 from the Honolulu Aquifer (see **Overlay A: Water Resources**).

Although the depth of fresh water under O‘ahu is as great as 600 to 1000 feet in the island's interior, these aquifers are unconfined. Unconfined aquifers do not have a caprock above them. Water in unconfined aquifers may have arrived recently by percolating through the land surface and is often considered very young in geologic time. One of the risks of an unconfined aquifer is contaminated material moving through the permeable materials directly above it. Widespread detection of pesticides and herbicides in the aquifers beneath agricultural fields and the more localized presence of volatile organic compounds beneath sites of known use or spillage have confirmed the aquifers' vulnerability to contamination. Overpumpage and salt water contamination are also threats to Oahu's unconfined aquifers. Vertical salinity profiles from deep monitor wells located in the Honolulu area indicate that the salinity of water at any particular depth in this important aquifer increased from 1970 to 1990, indicating that the thickness of the freshwater lens may be slowly shrinking.

Above ground, along the rift zone and in the Schofield ground water area, the Ko‘olau Mountains also house impounded water. Although the actual impounding structure in this area is unknown many areas of high level water are impounded by dikes, which are thin, near-vertical sheets of massive, low-permeability rock that intrude into existing rocks. They intersect at various angles and compartmentalize the more permeable Ko‘olau Basalt rock and trap groundwater. The Ko‘olau Basalt contains an extraordinarily intense dike complex with an estimated 7400 dikes totaling four kilometers wide in one transect. Although the water table is generally very flat, there are some small but important dike reservoirs in the Ko‘olau Mountains, with some water levels as high as 1300 feet above sea level (Walker, 1990). Although these aquifers are relatively small, they are important since they recharge the basal aquifers, provide streamflow, and yield significant amounts of potable water (about 15 million gallons per day).

Lastly, southern O‘ahu has some small areas with perched water, or areas where low-permeability alluvial deposits sufficiently impede the downward movement of ground water to allow a perched water body to develop within otherwise unsaturated rocks. Perched water however, is not a significant source of supply.

Surface Water Resources

Although surface water does not supply much drinking water for O'ahu, its instream uses are essential. Oahu's streams play a vital ecological role as habitat for numerous species of endemic freshwater fish, invertebrates and other aquatic organisms. Streams function as riparian corridors for many other non-aquatic species as well. They affect the physical, chemical, and aesthetic quality of receiving waters such as estuaries, bays, and near-shore coastal waters that are critical to the tourism-based economy of O‘ahu. Streams also have cultural, recreational, scientific and education values. Oahu's streams supply a flow of cool water for taro cultivation and other agriculture.

The KMW area contains nearly 500 miles of continuous-perennial (flowing yearlong) stream systems spread out throughout 43 named streams. Nearly half of the total stream mileage is contained within five stream systems: the Anahulu Stream, Paukauila, Waiawa Stream, Waimea River, and Ki‘iki‘i Stream (**See Map #2: Hydrological Surface Features**). Seventeen intermittent (flowing yearlong at upper elevations only, and intermittently at lower

elevations) streams also originate within the KMWP area with a notable concentration in the leeward Schofield Barracks area. Hawaii's streams typically have a unique flow characteristic that includes very large peak flows. Therefore, average discharge values are not necessarily the best indicator of available water during normal times. Median flows (flow exceeded 50% of the time) are a more accurate measure of typical instream conditions, and are useful for irrigation and storage purposes (HSA, 1990). Low flow information is useful for analysis of aquatic habitat requirements.

The Hawai'i Stream Assessment[5] (HSA, 1990) found four stream systems within the Ko'olau Mountains – Kahana, Maunawili, Hālawa, Makaleha/Ki'iki'i Stream – to be of outstanding value, based on ratings for aquatic, riparian, archaeological and recreational resources. Aquatic resources were defined as inclusive of fish, mollusks and crustaceans that rely on freshwater streams for habitat. The HSA considered the presence of certain native species as indicators of aquatic resource value and overall health of the stream system. Riparian resources include those streamside or terrestrial natural resources that may affect or be affected by the quality of stream ecosystems, such as native plant species, native forests, wetlands and water bird recovery habitat within the stream corridor, as well as threatened and endangered plant and bird species. Such resources offer useful indicators of the quality of stream watersheds. Cultural resources include stream-related cultural sites from prehistoric to historic times and sites where *kalo* (taro) still grow today. Other resources include *heiau*, habitation complexes, irrigation systems and *lo'i* (wetland taro patches), bridges, and mills. Recreational resources occur in diverse stream settings ranging from concrete urban canals to remote natural streams, including stream pools, waterfalls and banks that provide places for people to swim, fish, boat, hike, see wildlife, and enjoy scenic vistas. The ratings in each of those categories for those streams are summarized in the Table 2.

Table 2: Summary of Resources for Ko'olau Mountain Streams of Outstanding Resource Value

Stream	Aquatic	Riparian	Archaeology	Recreational
Kahana	Outstanding	Outstanding	Outstanding	Outstanding
Kawainui/Maunawili	Limited	Outstanding	Outstanding	Substantial
Hālawa	Limited		Outstanding	Substantial
Makaleha/Ki'iki'i	Moderate	Outstanding		Moderate/Outstanding

Source: Summarized from HSA, 1990

Water Supply and Consumption

In many communities, drinking water originates from "surface" water sources: lakes, rivers or streams. On O'ahu however, of its 265 million gallons used per day, groundwater provides essentially all municipal and domestic water for Oahu's growing population.[6] Surface waters

[5] The HSA is a statewide appraisal of Hawai'i streams conducted by the Commission on Water Resource Management. This study evaluated the aquatic, riparian, cultural, and recreational resources of each of the State's perennial streams. Streams with unknown resources could not be evaluated and are left blank in the table. Although more than ten years old, the HSA is still the only study that evaluates and ranks a range of stream resources that critically affect stream quality. It functions as a useful baseline for determining the health and quality of Oahu's streams today.

[6] In 1997, of the 217.3 millions gallons per day used on O'ahu, 97% came from ground water (DLNR, 2001a).

are used almost exclusively for agricultural purposes, and comprise only 14% the total supply (DBEDT, 1999). Other figures have suggested that agricultural and domestic users are still roughly equal as the two largest freshwater consumers, each using about a third of the supply. While agriculture is justifiably perceived as a large water consumer, the substantial increase in estimated recharge on Oʻahu in the 1980s has been attributed to irrigated agriculture (Shade and Nichols, 1996).[7] A major shift continues to occur as sugarcane and pineapple cultivation is replaced with diversified agriculture and urban development. Industrial and commercial users, at 7% and 27% respectively, consume the remaining one-third of the supply (USGS, 1998a).

Given current withdrawal rates, some officials at the State Water Commission believe that without any improvements to water management, particularly in conservation, all renewable island water resources will be exhausted by the year 2010 (Roumasset, et al., 1997). Hawaiʻi receives an average of 70 inches of rainfall, which translates to nearly 8,000 billion gallons of water per year, more than ten times the annual water use in the state. However, since much of this precipitation is often geographically concentrated and "flashy," not all of it makes it into our water supply. Water demand is greatest in the Honolulu area, making the southern Honolulu/Pālolo to Waiawa aquifers important for recharge purposes. The Hālawa, ʻAiea, Waimalu and Punaluʻu areas are also being overpumped, and the Moanalua – Pālolo area is being pumped to its sustainable yield (See **Overlay A: Water Resources**).

There is an abundance of wells on Oʻahu in nearshore areas around the periphery of the island; most of these however, have low water levels. High water level wells are found in rift zones near the eastern and western sides of the island and in the central part, where low-permeability features create high water levels. Wells can be found in almost every valley on the windward side of the Koʻolau Range, but are not as abundant on the leeward side. The City and County of Honolulu Board of Water Supply has wells at 61 stations in the KMW area (See **Overlay A: Water Resources**). There are also nine major manmade water systems in the KMW, the largest of which is the Waiāhole ditch system. During the peak of sugar production, it was extracting up to 32 million gallons per day from the windward side of Oʻahu. As sugar has been replaced by diversified agriculture, flow has dropped down to ten million gallons a day or less, depending on the time of the year (Lee, 2001). Other water systems include aqueducts, other ditches or canals that are often attached to dams, weirs or flumes. A number of surface water stations are maintained by the USGS in or near the KMW area; data for these stations is available in the Water Resources Data report (USGS, 2001b).[8] (**See Map#2: Hydrological Surface Features**)

[7] Since pineapple reduces natural evapotranspiration, it has been shown that non-irrigated pineapple cultivation increases return flow and recharge.

[8] These are located at the following streams: Kaukonahua [2](d), Kīpapa (d), Waikele (dmt), Waiawa (d), Hālawa [3](dcmts), Kalihi [2](d), Waiakeakua (d), Mānoa (dcmt), Mānoa-Pālolo (d), Maunawili [3](d), Makawao (d), Kamoʻoaliʻi (d), Haʻikū (d), Kahaluʻu (d), Waiheʻe (dcmt), Waikane (d), Kahana (d), Punaluʻu (d), Kaluanui (d), Waimea [2](d), ʻŌpaeʻula (d). The number in brackets [ ] indicates multiple stations. Letters after the station name designate the type of data provided for water year 2000 (d)discharge, (c)chemical, (m) microbiological, (t) water temperature.

3. Species and Ecosystems

"The forest is one of the most helpful friends of man and perhaps no other natural agent has done so much for the human race and at the same time has been so recklessly used" (Judd, 1918). The native forested ecosystem in the Koʻolau Mountains is indeed a biological treasure and one of the most important resources in the KMW area. It is a unique entity, originating from a limited number of species that voyaged great distances to reach the Hawaiian Islands. Over the centuries, each native Hawaiian species in the Koʻolau Mountains, plant, animal, snail or insect alike, has adapted ideally to the typical weather cycles and soils on Oʻahu. Some species are so well adapted to the Koʻolau Mountains that they are endemic, or found nowhere else on Earth. Each native Hawaiian species has evolved into a source of unique genetic information, providing possible medicinal or other practical uses to society. Collectively, the Koʻolau forests embody a host of positive values and provide innumerable services and benefits for the island of Oʻahu, primary among which is an estimated sustained yield of over 364 million gallons of water per day (DLNR, 2001a).

a. Vegetation

The forests of the Koʻolau Mountains are the cornerstone of the conservation strategy for the KMWP. They serve to temper environmental stresses and contribute to the overall health of the watershed (Pelkey, 1999). One of the critical functions of a forested watershed is that of an umbrella. Tree leaves, branches, and understory plants intercept rain before it reaches the ground, increasing the infiltration of the rainwater into the ground. Forests help to make stream flows more consistent and cleaner, benefitting surface water collection. The forest is one of the most effective means of preventing erosion, as the force of the rain and wind is buffered by trees, underbrush, and organic litter on the ground, protecting the soil in the process (Judd, 1918). As the roots of the trees and associated plants grip the mountainside like a soil anchor, they prevent soil from washing into the streams and the Pacific Ocean, protecting ocean reefs and marine life from excessive siltation.

A forested watershed also soaks up rainfall into its soil, roots, mosses, ferns, and leaves, acting as a sponge. When it is fully saturated the vegetation slowly releases water, delivering a consistent and dependable long-term water source. Forests also deposit fallen debris in the water, creating a mechanism to slow the flow and providing habitat for freshwater organisms. In forested areas, evapotranspiration is greatly suppressed, allowing much of the rainfall and condensed fog to infiltrate into the ground, percolate through the soil, and reappear as clean water, either in streams or ground water. In contrast, denuded watersheds are "flashy", sending floods of muddy water into streams during rain, and drying up rapidly when rains cease (HINHP, 1998; DoFAW, 1998).

Hawaii's forested watersheds also contribute to the high quality of the islands' waters, functioning as Oahu's kidneys, which, in the human body, filter impurities out of the blood. In a forested watershed, particles attach themselves to leaves, stems and well-graded soils, decreasing sediment and nutrient loading into streams and other waterways. Leaves or root systems can also absorb certain compounds such as nutrients.

Currently, the forested watersheds that create and protect water supplies in the Koʻolau mountains of Oʻahu are considered to be in relatively good hydrologic condition (Roumasset, et al., 1997). This is thought to be a direct result of Hawaii's long-standing policy of watershed protection, which resulted in dramatic improvements from the degraded conditions that prevailed at the turn of the century (DoFAW, 2001b).

Within the KMW area, the line between native and non-native vegetation communities is relatively well-defined, following elevation zones. On the leeward slopes of the Koʻolau Mountains, native and non-native vegetation converge on average at an elevation of 1400 feet, with the most pristine areas occurring over 1600 feet. On the windward side of the Koʻolau Mountains, vegetation changes from non-native to native at approximately 1000 feet elevation. This native band of vegetation is contiguous throughout most of the summit range of the Koʻolau Mountains, except for a break in the Nuʻuanu/Pali area.

Past and present land management practices, such as alien plant and animal introductions, agricultural development, and military and recreational use have also contributed to the alteration of native ecosystems in the Koʻolau Mountains (Cuddihy and Stone, 1990; Wagner et al., 1985). No areas have are untouched by humans, and as a result, little original forest remains, except on the ridges, highest gulches and along the summit (Sohmer and Gustafson, 1987). Even the highest reaches of the wet *ʻōhiʻa* (*Metrosideros polymorpha*) forests of the summit area are declining in cover, resulting in drier conditions and depletion of understory species (Obata, 1985).

Generally speaking, the northern portion of the Koʻolau Range is dominated by large intact native forest communities and contains areas with the highest native forest and biodiversity values. The windward side of the summit crest near Sacred Falls, Hauʻula Forest Reserve and Kaipapaʻu Forest Reserve also contains some of the most intact native forest and rare plants, as well as high value native stream fauna like damselflies and *oʻopu*. The Lowland Wet and Mesic Forest types, dominated by *ʻōhiʻa* and other tree or fern taxa are the prominent native ecosystems, especially in the wet central summit area, extending down leeward flanks toward Honolulu and Wahiawā.

The windswept ridges are very steep and are dominated by the Native Wet and Mesic Shrubland ecosystem type, which is characterized by grasses, ferns, and low growing, stunted shrubs (Gagne and Cuddihy, 1990). Secondarily dominant is the Wet Cliff ecosystem type, found on most of the windward slopes of the mountains. Below the range of *ʻōhiʻa* on Oʻahu is *koa* (*Acacia koa)*; the two species rarely form mixed stands (Mueller-Dombois, 1975).

High resource areas in the southern Koʻolau range, although not as intact as the north, include the areas around Wailupe and Hawaiʻiloa trail. Some of the lower mesic areas in this range contain some rare plants found nowhere else. The extreme southern edge of the KMW area also contains a small portion of native Dry Cliff ecosystem type. See **Map #3: Biological Resources**.

In total, the Koʻolau Mountains Watershed retains only 54 percent, or approximately 53,000 acres of its original vegetation (HINHP, 2000). Within the southern portion, the native

vegetation is extremely fragmented, as fingers of non-native vegetation have spread along the ridges and valleys. Most of the remaining native vegetation south of the H-3 highway is restricted to steep valley headwalls and inaccessible summit ridges. Alien vegetation dominates the rest of the landscape, and is noticeably prevalent in the urban areas near Moanalua Valley, and along the Pali and Likelike Highways. Species like Java plum (*Syzygium cumini*), mango (*Mangifera indica*) *Eucalyptus*, and early reforestation species such as silk oak (*Grevillea robusta*) and paperbark (*Melaleuca quinquenervia*) dominate many lower areas. Alien plants such as Christmas berry (*Schinus terebinthifolius*), strawberry guava (*Psidium cattleianum*), grasses and invasive herbs such as Koster's curse (*Clidemia hirta*) tend to colonize the ridgetops and sides of gulches in lower area. Non-native alien plants are described in more detail in a subsequent section on "Threats to the KMW" and in Appendix B.

Despite the existence of these non-native species, recent discoveries of many rare plant populations prove that the Koʻolau Mountains are still an area of considerable biological significance. According to the Hawaiʻi Natural Heritage Program's Rare Species Database (2002), two rare natural communities and 73 rare plants occur at 319 locations throughout the KMWP area. Thirty-seven of these plants are federally endangered plant species,[9] and many are endemic, meaning that Koʻolau Mountains are the only place in the world where they can be found.

b. Animal species

The Koʻolau Mountains also host a variety of native, as well as non-native animal species. The area includes eight rare vertebrate species, including six endangered bird species and the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*) (HINHP, 2002). The forests of the Koʻolau Mountains are prime native forest bird habitat on Oʻahu; in fact, the endangered Oʻahu *ʻelepaio* (*Chasiempis sandwichensis ibidis*) recently had large portions of the southern and central Koʻolau Mountains established as critical habitat.[10] The *ʻelepaio* are most common in riparian vegetation along streambeds and in mesic forest with a tall canopy and a well-developed understory (FWS, 2001). The *ʻŌhiʻa* Lowland Wet Forest is prime native forest bird habitat for species like the Oʻahu Creeper (*Paroreomyza maculata*) and the *ʻiʻiwi* (*Vestiaria coccinea*). The KMWP area also houses 34 rare invertebrates, including a variety of endemic tree snails and damselflies. Endangered species represent values that society has proclaimed important through the passage and implementation of state and federal endangered species laws. A full list of all rare species known from the Koʻolau range is shown in Appendix A.

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[9] *Bonamia menziesii*, *Chamaesyce deppeana*, *Chamaesyce rockii*, *Cyanea acuminata*, *Cyanea crispa*, *Cyanea grimesiana* ssp. *grimesiana*, *Cyanea humboldtiana*, *Cyanea koolauensis*, *Cyanea st-johnii*, *Cyanea truncata*, *Cyrtandra dentata*, *Cyrtandra polyantha, Cyrtandra subumbellata*, *Cyrtandra viridiflora*, *Diellia erecta*, *Eugenia koolauensis*, *Gardenia mannii*, *Hesperomannia arborescens*, *Isodendrion longifolium*, *Labordia cyrtandrae*, *Lobelia gaudichaudii* ssp. *koolauensis*, *Lobelia monostachya*, *Lobelia oahuensis*, *Lysimachia filifolia*, *Marsillea villosa*, *Melicope lydgatei*, *Myrsine juddii*, *Phlegmariurus nutans*, *Phyllostegia hirsuta*, *Phyllostegia parviflora* var. *parviflora*, *Plantago princeps*, *Pteris lydgatei*, *Sanicula purpurea*, *Schidea kaalae*, *Tetraplasandra gymnocarpa*, *Trematobelia singularis* and *Viola oahuensis* (HINHP, 2002).

[10] Three core *ʻelepaio* subpopulations are extant in the KMW: in the southern Koʻolau Mountains, central Koʻolau Mountains, and Waikane-Kahana.

A primary non-native mammal of concern in the Koʻolau Mountains is the feral pig (*Sus scrofa*), as they are the largest ground-disturbing force in the native forest. These animals provide positive contributions to the value of the forest in terms of the recreational benefits of hunting and as food. If left uncontrolled however, they have the potential to cause serious damage to the watershed; even if controlled one pig can have a significant impact on highly sensitive areas. Other mammal species in the KMW area include feral cats (*Felis catus*), dogs (*Canis familiaris*), the house mouse (*Mus musculus*), mongoose (*Herpestes aruopunctatus*), and rats (*Rattus rattus, R. exulans*). Rats commonly occur in forested habitats and have been documented up to the summit area of the Koʻolau range (USFWS, 2000). Some documented non-native bird species from the KMW area include the Shama thrush (*Copsychus malabaricus*), Japanese bush warbler (*Cettia diphone*), Japanese white-eye (*Zosterops japonicus*), red-vented bulbul (*Pycnonotus cafer*), red-whiskered bulbul (*Pycnonotus jocosus*), red-billed leiothrix (*Leiothrix lutea*), yellow-faced grassquit (*Tiaris olivacea*), common mynah (*Acridotheres tristis*), spotted dove (*Streptopelia chinensis*), zebra dove (*Geopelia striata*), and the barn owl (*Tyto alba*) (USFWS, 2000). Several species of introduced reptiles and amphibians inhabit the Koʻolau Mountains as well, including frogs, toads (*Bufo marinus*) and lizards. Many invertebrates such as mosquitoes (*Aedes* spp. and *Culex* spp.) and black twig borers (*Xylosandrus compactus*) populate the watershed area as well.

The streams of the Koʻolau Mountains harbor a diversity of life forms, including freshwater fish, mollusks, crustaceans and insects. Although the diversity of native species in Hawaii's streams is low, most of these species are endemic to the Hawaiian Islands. The presence of native stream fauna is often used as an indicator of the health of the native aquatic system. The Hawaiʻi Stream Assessment (1990) used four native species, three species of *oʻopu* (*Lentipes concolor*, *Awaous stamineus*, and *Sicyopterus stympsoni*) and the *hihiwai* (*Neritina granosa*) as indicator species representative of potentially high quality stream ecosystems, even though these species are generally thought to be declining in native stream ecosystems. Other native species include the shrimp *ʻōpaʻe kalaʻole* (*Atyoida bisulcata*), eleotrid (*Eleotris sandwicensis*), prawn *ʻōpaʻe ʻoehaʻa* (*Macrobrachium grandimanus*), mullet *ʻamaʻama* (*Mugil cephalus*), and snail *hapawai* (*Theodoxus vespertinus*). Introduced species, also common in Hawaiʻi streams, can prey upon and compete with native stream life. Such species include swordtails (*Xiphophorus helleri*), Japanese loaches (*Misgurnus anguillicaudatus*), catfish (*Hypostamus* spp.) and mosquitofish (*Gambusia affinis*), as well as wrinkled frogs (*Rana rugosa*), Tahitian prawns (*Macrobrachium lar*) and crayfish (*Procambarus clarkii*) (USFWS, 2000).

B. Sociocultural Resources

While biological resources like plants and animals are often thought of as the only parts of an ecosystem, humans have left an indelible fingerprint on nearly every corner of the planet. Some areas of the Koʻolau Mountains are relatively pristine, but all have been affected by human activity in some way or another. People must be considered an important component of any ecosystem, as sociocultural resources can influence the watershed ecosystem in innumerous ways. It is important to explore the historical and current land uses as well as the impact humans have had on the land. These factors frame our ascribed values of the Koʻolau watershed, and determine what kinds of activities will be possible and successful in resolving watershed issues.

1. Land Ownership, Land Use Zones, and Land Management

Within KMWP area, there are 25 major landowners holding properties of more than 100 acres. These landowners, as well as the acreage of their holdings are listed in Table 3. Landowners that are also members of KMWP are highlighted. Table 3, with its numerical ranking by size also serves as a legend for **Map #4 and Overlay B: Land Ownership**.. Land ownership is spread across the landscape between public and private landowners, with less than 45 percent of the KMW area publicly owned. This mottled effect provides many opportunities for joint on-the-ground projects.

Table 3: Landowners in the Koʻolau Mountains Watershed Partnership Area with holdings over 100 acres

	Landowners of >100 Acres	**Acreage[11]**	**Percent**
1	Kamehameha Schools	26,913	27.86
2	State of Hawaiʻi (DLNR)	25,660	26.57
3	U.S. Army	7,375	7.64
4	Dole Food Company, Inc.	5,553	5.75
5	City and County of Honolulu	4,748	4.92
6	U.S. Fish and Wildlife Service	4,525	4.69
7	Samuel M. Damon Trust Estate	2,932	3.04
8	Hawaiʻi Reserves Inc.	2,813	2.91
9	Kualoa Ranch Inc.	2045	2.12
10	Elizabeth M. Stack, et al.	1,722	1.78
11	State of Hawaiʻi Department of Hawaiian Homelands	1,369	1.42
12	Austin Income Tr. 1971, et al.	1,323	1.37
13	Queen Emma Foundation	1,207	1.25
14	Manana Valley Farm, LLC	1,170	1.21
15	SMF Enterprises Inc.	1,138	1.18
16	Koʻolau Management Inc.	885	0.92
17	Castle and Cooke, Inc.	878	0.91
18	Bishop Museum	646	0.67
19	Agribusiness Development Corp.	573	0.59
20	Hiram L. Fong Jr.	491	0.51
21	James H. Pflueger, et al.	316	0.33
22	Hawaiian Humane Society, et al. (Tiana Partners, et al.)	280	0.29
23	Oʻahu Country Club	250	0.26
24	Roman Catholic Church	155	0.16
25	Steven C. Cunningham, et al.	151	0.16
	Landowners of <100 acres	1,466	1.52
	Total	**96,584**	**100%**

[11] The land area is a calculated approximation based on City and County of Honolulu Tax Map Key Data.

Land Use Zones

Zoning regulations are important as they dictate what kinds of uses and projects are acceptable in any given area. These land uses as well as the required permits or necessary management contingencies, are delineated in the Hawai‘i Administrative Rules, Title 13, Chapter 5. Land use zones within the KMW area are displayed in **Overlay C: Land Use Zones**.

GIS analysis suggests small portions of the KMW area are actually zoned as “Urban” (0.4%) and “Agricultural” (0.4%). All other lands have been zoned as Conservation District – a classification driven by the recognition that forested lands protect water resources for other uses. Within the Conservation District zone, different areas of the Ko‘olau Mountains have various **subzone** designations that regulate the types of activities allowable in a particular area.

For example, the summit portions of the KMW area, comprising about 28 percent of the total area, have been designated as “Protective” subzone to protect water resources as well as the native ecosystems with the plants and animals they harbor. Additionally, a few smaller parcels managed by the State Department of Hawaiian Homelands (DHHL) also have “Protective” designation for the “preservation and enhancement of designated historic or archaeological sites and designated sites of unique physiographic significance” (DLNR, 1994). “Protective” is the strictest of subzone designations, in which physical facilities are not allowed. Habitat improvement, site restoration, vegetation protection (including noxious weed removal), and control of animals and plants, including fishing and hunting are approved activities (Stone and Scott, 1985).

The areas outside of “Protective” designation have mostly been classified as “Resource” subzone areas, the objective of which is to develop areas to ensure sustained use of the natural resources. Comprising about 69% of the total area, these lands include land uses such as parklands, forestry lands, and outdoor recreation areas. A few small areas totaling 1.4 percent of the land area are comprised of the “Limited” subzone, which is designated for areas susceptible to erosion, and where these natural conditions suggest some constraints on human activities. The KMW area also contains a small percentage (0.3%) of the “General” subzone, which is designed for open space where specific conservation uses may not be defined, but where urban use is not allowed (DLNR, 1994).

Past and Present Land Management

In ancient Hawai‘i, the traditional system of land and water tenure and management centered on the *ahupua‘a*, a wedge of land that extended from the mountains to the ocean and often followed natural watershed divisions. Land and water resources were under the control of the *ali‘i* (chief), providing an efficient means of constructing land and water infrastructure. This infrastructure consisted of a highly advanced system of irrigation ditches which would carry water from mountain streams into *lo‘i*. Native Hawaiians drew their water supplies from fresh water springs, lakes, streams and shallow wells (Handy and Handy, 1972). Strict *kapu* (taboo) governed water resources, and the *kanawai* (laws of water) eventually became the law of the land. Pre-European Hawai‘i was not however, an ecological utopia. Although environmental change certainly accelerated after Western contact, even before that large

stretches of dry, lowland forests had been destroyed, primarily by fire in slash-and-burn agriculture.

In the late 1700s, disease and recruitment by plantations drew Hawaiians away from their traditional taro system and led to the transformation of these lands into abandoned fields. In 1793, Vancouver made a gift to Kamehameha I that would eventually affect the natural resources of Hawai‘i for many years to come. Cattle, brought from South America, so impressed Kamehameha that he declared a *kapu* on them shortly thereafter. Starting in the 1800s, many areas of the Ko‘olau Mountains were converted for cattle ranching. Cattle were allowed to roam free and unharmed, and with no natural enemies and an abundance of forage, they rapidly multiplied until they had become a public nuisance by 1815. Reports of cattle destroying farms, attacking people and eating the thatch off houses became widespread. Free reign of cattle also resulted in what Griffith (1902) called the "total destruction of all the undergrowth and trees on the lower slopes" to the point where the "remaining forests [were] confined to the upper slopes and the more inaccessible canyons."

Sandalwood (*Santalum* spp.) traders also made inroads of their own into the forests of Hawai‘i. Haltingly begun in 1790, the trade in sandalwood had become a major undertaking by 1811 and was at fever pitch from 1815 to 1826. By the early 1830s, the boom of sandalwood cutting was over. Nearly all of the sandalwood had been harvested, leaving only a network of well-used trails that undoubtedly helped spread exotic plants throughout former sandalwood areas. Additional impact continued in the forests, as large numbers of whalers stripped thousands of acres of forestland for firewood. By the late 1850s, sugar plantations began to take hold on the islands, consuming large quantities of firewood to fuel their mills.

In spite of an ongoing search for new sources of irrigation water, supplies were soon stretched to their limits. Concern for watershed protection rose in response. Plantation owners began calling both for reforestation to protect the watersheds and for the control of domestic and feral herbivores, which were continuing their destructive ways. Sugar plantations were making their own inroads into the forests, clearing the remaining lowland mixed forests that had survived the traditional slash-and-burn agriculture of pre-contact Hawaiians. In 1876, the legislature authorized the Minister of Interior to set aside and protect wood and forest lands that were valuable either as watersheds or as sources of timber. Sentiment for reforesting the slopes behind Honolulu was especially strong.

Shortly thereafter, in 1879, Oahu's vast underground storage of pure, fresh water was discovered on the ‘Ewa plains. Within 10 years, a series of artesian wells were drilled within the Honolulu city limits. By 1888, artesian water was supplying most of Honolulu's water needs. This discovery led to a water boom on the island as ranchers and sugar plantation developers commenced furious drilling. Within 20 years, boom turned to bust. Abandoned and neglected wells wasted millions of gallons of water, and by the turn of the century, O‘ahu was in water panic. Demand was growing, but its wells were salting up and water levels dropping.

Water scarcity was the trigger for the establishment of watershed protection laws. From 1913-1925, the task of water management was appointed to various bodies: the Department of

Public Works, the Honolulu Water Commission, and the Honolulu Sewer and Water Commission. None were entirely successful. The following legislative session in 1929 led to the creation of the Board of Water Supply (BWS). Its immediate objectives had been to modernize the system, meter all water distributed and seal all faulty, leaking artesian wells in an effort to halt the waste of fresh water. In the ensuing years, these and other goals were attained.

In addition to establishing the BWS, O'ahu also took steps to protect the mountain watersheds as forest reserves. Reforestation efforts from 1908 to 1933 averaged 400,000 trees per year, with over half of them being eucalypts. By the onset of World War II, the forest reserve network made up 25% (1.2 million acres) of the land area in Hawai'i. In 1934, the federally sponsored Civilian Conservation Corps (CCC) program arrived in Hawai'i. Reforestation reached its peak during 1934-41, when an average of nearly two million trees were planted annually in forest reserves throughout the state. On O'ahu, the CCC was organized in two separate divisions, the Wahiawā Camp and the Honolulu Unit, each with about 200 men and 10 supervisors. Hundreds of miles of trails and fences were built, as was an extensive infrastructure of nurseries, roads, buildings, telephone lines and signs. Tons of seed were collected for reforestation efforts. Feral animal control actions removed approximately 40,000 animals (25,000 of these being goats) from forest reserves between 1929-1930 (LeBarron and Korte, 1970). In the end, most of the severely eroded areas had been reforested, and feral livestock numbers were at manageable levels. At the time, much of the need to protect water resources stemmed from the high amounts of water needed to produce sugar.[12] Currently, with sugar production waning in areas such as Waialua, the water formerly used for irrigating sugar cane lands is now being used for various diversified crops and traditional farming such as taro cultivation (HHP, 2000).

In 1987, the State Water Code was adopted by the Hawai'i Legislature, a move that set in place various layers of protection for all waters in the Hawaiian Islands. The State Commission on Water Resource Management (CWRM) – also known as the Water Commission – sets policies and approves water allocations for all water users, including the Honolulu Board of Water Supply. Although the Code assigned primary responsibility for the protection of groundwater resources to the State Department of Health, the Board of Water Supply continues to maintain policies to regulate and protect watersheds and activities over Oahu's basal aquifers.

USFWS' newly acquired O'ahu Forest National Wildlife Refuge is the only area within the KMWP specifically dedicated to the protection of native forest systems and species, particularly rare, endangered and threatened species. The U.S. Army manages three active military reservations within in the KMWP area. These lands – the Kahuku Training Area, Kawailoa Training Area, and Schofield Barracks Military Reservation – are either owned by the federal government, or leased from various state and private landowners. The military are stewards of approximately 31,000 acres within the KMWP area. State managed lands consist of recreational and conservation areas. There are seven state areas identified for recreational use, wayside or State Parks, and nine State Forest Reserves. There is a variety of other

[12] It takes one million gallons of water to produce one ton of sugar (Wilcox, 1996).

properties currently being leased in the KMW area, although the management level of these areas is not known. Lessees with over 100 acres of land within the KMWP boundary include:

- Koʻolau Agricultural Co. Ltd. (16,592 acres from Kamehameha Schools)
- Oʻahu Sugar (2774 acres from Kamehameha Schools, and Bishop Museum)
- Hawaiian Electric Co. (1300 acres from Dole Foods Ltd.)
- Hawaiʻi Housing Authority (1190 acres from the State of Hawaiʻi)
- Aloha Council Boy Scouts of America (789 from the State of Hawaiʻi)
- Plants & Environment Inc. (313 acres from the City and County of Honolulu)
- Paradise Park, Inc. (155 acres from the Roman Catholic Church).

Table 4 displays the other managed areas within the KMW Area. The letters in the left column also function as a legend for **Overlay D: Management Designations**. Part 4 of this section, "Recreational/Educational Opportunities" contains more details on the State Parks within the KMW Area.

Table 4: Managed Areas within the KMW Area

Map Legend Key	Management Designations	Type	Area (acres)
A	Oʻahu Forest National Wildlife Refuge	Wildlife Refuge	4,525
B	Kahuku Military Training Area	Military Training Area	4,118
C	Kawailoa Military training Area	Military Training Area	23,124
D	East Schofield Barracks Military Reservation	Military Training Area	3,743
E	ʻEwa Forest Reserve	Forest Reserve	5,763
F	Hauʻula Forest Reserve	Forest Reserve	1,416
G	Honolulu Watershed Forest Reserve	Forest Reserve	7,270
H	Kaipapaʻu Forest Reserve	Forest Reserve	970
I	Kāneʻohe Forest Reserve	Forest Reserve	64
J	Kuliʻouʻou Forest Reserve	Forest Reserve	215
K	Pūpūkea – Paumalū Forest Reserve	Forest Reserve	854
L	Round Top Forest Reserve	Forest Reserve	26
M	Waiāhole Forest Reserve	Forest Reserve	1,496
N	Kahana Valley State Park	State Park	5,216
O	Makiki Tantalus State Park	State Park	19
P	Sacred Falls State Park	State Park	1,312
Q	Waʻahila Ridge State Park	State Park	72
R	Keaīwa Heiau State Recreation Area	State Recreation Area	385

There are also at least two protected area management units in development. There is a current proposal to establish the Waimānalo Forest Reserve to include Mount Olomana, a state monument located just outside the KMWP boundary. The State Division of Forestry and Wildlife has submitted a nomination to designate the upper one-third of the Poamoho region as a Natural Area Reserve (NAR).

2. Population and Local Communities

Although there are few residents living within the KMW area, the Koʻolau Mountains support a massive urban population that in many cases directly abuts the watershed management boundaries. While these residents and local communities may not be official stakeholders in KMWP, it is imperative to gain an understanding of the neighboring communities as well as have the communities understand both the concept of the watershed and the specific context of the one in which they live.

Areas with the highest population density in the immediate watershed area are Honolulu, Mililani Mauka and Pearl City / ʻAiea on the leeward side and Kāneʻohe on the windward side. These areas can be threats, potentially introducing fire ignition sources, invasive weeds and feral animals into the watershed. Areas with the lowest population density include the entire stretch of coastline from Haleʻiwa to Waiāhole-Waikane. (See **Map #5: Population Density**).

Some indicators, such as the percent of owner-occupied dwellings and the length of residence, suggest a heightened sense of stewardship and pride. These indicators may denote people who are "tied to the land" and interested in the issues surrounding and affecting their neighborhoods. They can also reveal the sense of connection people have to each other and to the watershed. One could reason that a stable community, with long-time residents and landowners, might have a greater investment and interest in being better stewards of the land. This has important implications for management and outreach, for if people are not involved with their communities, then they may be less likely to support common resource management issues such as those within the KMWP. Areas with the highest percent of owner-occupied dwellings tend to be newer developments such as Mililani Mauka (at 85%), or older, more established communities such as Upper ʻAiea, Upper Mānoa and ʻAina Haina. By far, the areas with the lowest owner occupancy were in the military-dominated areas, with rates barely reaching 3 percent. After the military areas, the lowest percentages for these indicators were found in Haleʻiwa. (See **Map #6: Percent of Owner-Occupied Dwellings**.)

Median Age can also provide insight into the demographic profile of a community, which could influence the type of communication and networking approaches selected. Median age was highest in the Nuʻuanu, Mānoa, Tantalus and Woodlawn areas, and lowest in the military-dominated areas. Of the non-military areas, Hauʻula, Mililani Mauka, Waimānalo and Kaukonahua exhibited the lower median ages. (See **Map #7: Median Age**.)

3. Cultural Resources and Traditional Practices

The cultural resources within the Koʻolau Mountains include archaeological, historic and modern elements. Examples of archaeological sites are agricultural or taro *loʻi* sites, habitation sites, rock shelters, burial caves, irrigation sites, pond sites, habitation terraces, walls and enclosures. The Koʻolau Mountains house a number of cultural or historic sites. Kaniakapupu in the Luakaha area of Nuʻuanu Valley is one of these historically significant sites. It served as the summer residence of King Kamehameha III (Kauikeaouli) in the 1840s and is believed to have been built on the site of a *heiau*. The State Historic Preservation Division (SHPD) of the Department of Land and Natural Resources (DLNR) has established

the site as a Historic Preserve, which designates the site for preservation and protection for its historic significance. However, since ancient Hawaiians did not use the *mauka* portions of the Koʻolau Mountains for residence, relatively few settlements or archaeological resources have been located in these areas (Collins, pers.com, 2001). The Koʻolau Mountains have not yet been completely surveyed for cultural resources.

Historic sites include those associated with both ancient mythology and legend, as well as more recent history. Hawaiian mythology features the Koʻolau Mountains as a prominent location. Wakea, the Sky-Father, and Haumea, the Earth Mother, lived there. The sanctuary of Lono, a *heiau* considered the most sacred on Oʻahu, also calls the Koʻolau Mountains home. The Koʻolau Mountains were also the backdrop for the epic battle pitting Kumuhonua, foundation of the Earth, against Wakea and Haumea. The upland watershed forest, or *wao akua*, is deeply significant in Hawaiian culture. Known as the "Forest of the Gods," it is regarded with great respect and spiritual awe. There are many Hawaiian stories, legends, and chants related to areas of the Koʻolau Mountains, some of which stopped the H-3 highway from going through Manananui valley in Moanalua.

The KMW area also includes some post-Western contact historic features. According to the State Historic Preservation Division (SHPD), structures such as bridges, sugar mills, and irrigation systems can be considered historic resources if they are 50 years or older. Many of the trails within the KMW area were constructed by the Civilian Conservation Corps of the 1930s and are now old enough to qualify for the Historic Register.

Modern cultural elements encompass a range of traditional, cultural, religious, and subsistence activities that Native Hawaiians have engaged in for many centuries. The diverse geography of the Koʻolau range provides various raw materials for medicine, food, woodworking and weaving, including a wealth of resources for gatherers practicing native Hawaiian arts and traditions. Subsistence use of these resources in the watershed has also been identified as vital to families for economic, cultural, and social reasons.[13] Such activities include pig hunting, gardening, protection of fresh water resources, and the collection of native plant materials. A permit system at DoFAW regulates harvesting of forest products and recreational uses in State Forest Reserves, but enforcement of regulations on forest use is limited by a personnel shortage. Effectively there is little actual control and use of the reserve forests is largely unrestricted (Vieth, et al., 1999). Collection was formerly important in extirpation of rare *Achatinella* tree snail populations, although losses to these causes are much less now than before 1940, when tree snail collecting was still a popular hobby.

Native plant material is also known to be collected in the *ʻōhiʻa* lowland wet forests of the Koʻolau Mountains for lei making and hula dancing. There are few substitutes for forest gathering of certain *lei* materials, and excessive collecting might lead to endangerment of the plant species. One study (Vieth, et al., 1999) found that more than two-thirds of the *hula halau* on Oʻahu gather *hula lei* materials from the forest. As wild plant resources become

[13] Subsistence has been defined as a valuable ecosystem service that encompasses the customary and traditional use of "wild and cultivated renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools, transportation, culture, religion, and medicine, for barter or sharing, for personal or family consumption and for customary trade" (Governor's Task Force on Molokaʻi Fishpond Restoration, 1993).

scarcer, and the corresponding chances of finding these resources decreases and the time spend searching increases, many *halau* stated they would be more likely to consider alternative plant sources such as commercial purchase and backyard growing.

Cultural practices may have an effect on landowners, as access is an important issue for many native practitioners. In the landmark 1995 Public Access Shoreline Hawai‘i (PASH) vs. Hawai‘i County Planning Commission (HPC) decision, the Hawai‘i Supreme Court made a strong statement regarding native Hawaiian rights. The court ruled that the HPC has an obligation to protect the traditional and customary rights of Native Hawaiians, recognizing that unique conditions are placed on the rights of landowners in Hawai‘i. The decision recognized the traditional relationship Native Hawaiians have with the land and the importance of maintaining that relationship. However, the fallout of the PASH decision has been the subject of much discussion, and PASH rights, as they have become known, have been embroiled in much controversy (Eager, 1997). The issues, some of which have not been resolved, include questions such as: What is considered to be customary and traditional? In a dispute, who has the burden of proof? When are rights claims unreasonable? Who is a Native Hawaiian? Who is liable for acts done in the name of PASH? Can PASH override laws such as the federal Endangered Species Act?

4. Recreational/Educational Opportunities

The lynchpin to recreational use in the Ko‘olau Mountains is access, which is most easily achieved via the trail network running through the range. Trails, with both positive and negative attributes, are important to the management of the watershed. From a management perspective, trails provide points of ingress to more easily and safely conduct activities such as surveys, ungulate control, search-and-rescue efforts and fire management. Trails also represent avenues to experience cultural history and historic trail features, as well as conduits for economic, ecotourism and of course, recreational opportunities. Trails also tend to serve as animal corridors, areas where ungulates will most likely travel and be found. Overuse of trails can lead to higher compaction and more water runoff. Hikers or animals using the trail also contribute to the spread of weeds. If the trail is large enough, it can create a gap in the forest canopy, changing the light regime of the forest and creating edge areas, which are ecological niches that are often usurped by opportunistic invasive alien species.

Trails traverse nearly all of the ridges in the southern portion of the watershed. In the central area of the range, few of these arterials are interconnected, while in the northern portion, the Ko‘olau Summit trail forms a network across the whole section. Not all trails within the Ko‘olau Mountains are open to the public; in fact, the majority occur on private land. **Overlay E: Recreational Use and Resources** delineates the public trails promoted by the Nā Ala Hele Program,[14] private trails and access roads to get to these trails. Table 5 lists and classifies the public trails within the KMW area.

[14] Nā Ala Hele, administered by DLNR under DoFAW, was established in 1988 through Chapter 198D Hawaii Revised Statues, in response to public concern about the increasing loss of public access to trails and the threat to historic trails from development pressure.

Table 5: Nā Ala Hele Trail and Access System within the KMWP Area

NAME OF TRAIL OR ACCESS ROAD	CLASSIFICATION (NAH Program - Commercial Trail Tour Activity - Federal Recreational Trails Program Designation)
1. Kaunala Trail	Rural, Non-motorized
2. Hauʻula Loop Trail	Rural, Commercial, Non-motorized
3. Maʻakua Gulch Trail (currently closed)	Wildland, Non-motorized
4. Maʻakua Ridge Trail	Rural, Commercial, Non-motorized
5. Poamoho Access Road (State Portion) and Trail	Wildland, Sensitive, Motorized-Diversified, Non-motorized
6. Schofield-Waikane Trail	Sensitive, Non-motorized
7. Mānana Trail	Wildland, Sensitive, Non-motorized
8. Waimano Trails (upper, lower, and access)	Rural, Wildland, Non-motorized
9. Honolulu Mauka Trail System[15]	Urban, Rural, Commercial (Kālawahine, Pauoa Flats) Non-motorized
10. Maunawili Trail	Rural, Commercial, Non-motorized
11. Maunawili Pali Access Trail	Rural, Commercial, Non-motorized
12. Maunawili Falls Trail (State Portion)	Urban, Non-motorized
13. Maunawili - Waimānalo Access Road	Rural, Commercial, Non-motorized
14. Maunawili Ditch Trail	Rural, Non-motorized
15. Wiliwilinui Trail	Urban, Wildland, Sensitive, Non-motorized
16. Hawaiʻiloa Ridge Trail	Wildland, Sensitive, Non-motorized
17. Kuliʻouʻou Valley Trail	Rural, Commercial, Non-motorized
18. Kuliʻouʻou Ridge Trail	Rural, Wildland, Commercial, Non-motorized

Source: Nā Ala Hele Trail and Access System, DoFAW

Within the KMW area, DoFAW and the Nā Ala Hele Program conduct periodic trail maintenance, which includes cutting of encroaching vegetation and trail surface improvements along all or portions of the public trails. Many private organizations, such as the Sierra Club and the Hawaiian Trail and Mountain Club also help to maintain trails and lead numerous hikes throughout the region.

Hiking is the most popular recreational activity within the KMW Area. Unauthorized trespassing and creation/cutting of new hiking trails, sometimes deep into the watershed area,

[15] The Honolulu Mauka Trail System includes Tantalus Arboretum, Kanealole, Maunalaha, Nahuina, Makiki Valley, ʻUalakaʻa, Moleka, Mānoa Cliff, Kalāwahine, Puʻu ʻŌhiʻa, Pauoa Flats, Nuʻuanu, Judd, ʻAihualama, Mānoa Falls, Kolowalu, Waʻahila, and Puʻupia)

can be a problem in the Koʻolau Mountains, as it represents a significant liability problem in case of injury or death. Safety can be a potential concern especially in more remote mountainous trails that traverse over and between public and private lands, or travel near areas with hazardous materials. Chapter 520, Hawaiʻi Revised Statutes, is a state law that provides liability protection to private landowners for public recreational activity.

Trails within the KMW area often intersect or lead to hunting areas. Hunting of feral pigs and goats is a popular sport and a source of food for some Oʻahu residents. Goats, while extant in the Koʻolau range, are rarely encountered and not a significant presence at this time. The Division of Forestry and Wildlife (DoFAW) manages eight public hunting areas (PHA) in the Koʻolau Mountains, where the primary game animal is feral pig (See **Overlay E: Recreational Use and Resources)**. These include:

- Kuliʻouʻou Unit C, in the Kuliʻouʻou Forest Reserve
- Wailupe PHA Unit C, in the Honolulu Watershed Forest Reserve
- Nuʻuanu PHA Unit F, in the Honolulu Watershed Forest Reserve
- Waimano PHA Unit B, in the ʻEwa Forest Reserve
- Poamoho PHA Unit C, in the ʻEwa Forest Reserve
- Hauʻula PHA Unit B, in the Hauʻula and Kaipapaʻu Forest Reserves
- Kahana PHA Unit C, in the Kahana Valley State Park, and
- Pūpūkea PHA Unit, in the Pūpūkea-Paumalū Forest Reserve.

DoFAW provides a public hunting season with liberal bag limits in order to promote feral pig control (USFWS, 2000). State regulations (Hawaiʻi Administrative Rules, Title 13, DLNR) govern hunting seasons and the methods of harvest. The State of Hawaiʻi also has regulations pertaining to the ancillary Forest Reserves and Nā Ala Hele trails and access roads. The well-established State Parks Division recreation areas within the KMW Area are detailed in Table 6 and displayed on **Overlay D: Management Designations**.

Table 6: State Parks within the KMWP Area

Kahana Valley State Park Location: 52-222 Kamehameha Highway	5,216 acres
Scenic wildland valley. Activities include: swimming, bodysurfing, beach-related activities, picnicking, camping and viewing of Huilua Fishpond at beach area; hardy family hike (4.9 miles) and fruit picking in lushly vegetated forest; picnicking in coconut grove; pig hunting in public hunting area.	Park hours: daylight
Makiki Tantalus State Park and Puʻu ʻUalakaʻa State Wayside Off of Round Top Drive near Makiki Street, Honolulu	50 acres
Activities: Forested area on a cinder cone close to downtown Honolulu with lookout for providing sweeping view of southern Oʻahu from Diamond Head to Pearl Harbor, including Honolulu and Mānoa Valley. Picnic shelters available. Trailhead for ʻUalakaʻa Loop Trail (1-mile loop).	Park hours: See note. *

Keaīwa State Recreation Area End of ʻAiea Heights Drive, ʻAiea Heights, ʻAiea.	385 acres
Forest recreation: picnicking, camping and hardy family hiking (4.8-mile loop trail); rustic facilities. Remains of *heiau hoʻola* (temple of healing) and specimens of medicinal plants on display.	Park hours: See note.*
Waʻahila Ridge State Recreation Area End of Ruth Place, via Peter Street from St. Louis Drive off Waiʻalae Avenue, St. Louis Heights, Honolulu.	72 acres
Wildland picnicking on a Norfolk Island pine forested ridge. Views of Mānoa and Pālolo valleys. Hardy family hiking in the forest reserve.	Park hours: See note.*
Nuʻuanu Pali State Wayside Location: Nuʻuanu Pali summit from marked access road off Pali Highway (Highway 61). Part of the Honolulu Forest Reserve	3.0 acres
Impressive view of windward Oʻahu from brink of *pali* (cliffs) at 1200 feet elevation, Koʻolau Range. Winds are usually so strong that one can lean against the wall of wind.	Park hours: See note.*

Source: DLNR Website: http://www.hawaii.gov/dlnr/dsp/oahu.html

* PARK HOURS: Entrance gates of certain parks on Oʻahu are closed at nights. Parks are open 7 AM to 7:45 PM from April 1 to Labor Day, and 7 AM to 6:45 PM from the day after Labor Day to March 31.

Kalihi Valley and Waimano Gulch State Park Reserves are not well-established recreation areas. They have no signage, are infrequently maintained and do not appear on State Park information packages. The State Parks Division is currently investigating the feasibility of leasing Kalihi Valley State Park as a Native Hawaiian Education Center (DLNR, 2001b). Sacred Falls State Park, also within the KMW boundaries, has been indefinitely closed since the tragic rockslide of May 1999. The Nuʻuanu Reservoir is the most active fresh water fishing area on Oʻahu, the headwaters of which originate in the KMW area. Catfish and tilapia are the catch of choice in this area.

Ecotourism[16] can provide an avenue for education and a potential source of income for private landowners within the KMWP. The Nā Ala Hele Program within DoFAW manages and regulates commercial trail tours, establishing a protocol that could serve as a template for private landowner ecotourism ventures. In addition to rainforest hiking, examples of forest-related ecotourism activities include: geology, astronomy tours, backpacking, trekking, mountain camping, watchable wildlife, (ethno-)botany tours, research expeditions, nature centers, nature trails/walks, game viewing, elder hostels, bicycle tours, mule rides, Hawaiiana/lifestyles, outback 4-wheel drives, trekking, and eco-air tours. While the wedding of education and profit sounds attractive, ecotourism can have negative ecological and financial impacts if poorly conducted. It is the not within the purview of this management

[16] Ecotourism has been defined as nature-based travel to natural areas to experience and study unique flora, fauna, and culture in a manner that is ecologically responsible, and sustains the well-being of the local community.

plan to either advocate or discommend ecotourism for individual landowners; its intent is merely to point out the uses and possibilities that exist within the watershed area.

5. Infrastructure and Facilities

Since few areas of the KMW are developed, it is important to recognize existing infrastructure within the management area. Human-built structures are often conduits for traffic and must be maintained to minimize any unwanted impacts, such as overuse of sensitive sites, inadvertent introduction of weeds on hikers' boots or vehicles, heightened liability exposure, increased potential for damage to the water system or contamination of the water supply. These structures can also be beneficial for recreation and management purposes, providing access routes or infrastructure to manage important resources. To date there has been no database compilation of significant structures or other infrastructure such as existing fences.

Some known features include the ʻŌpaeʻula /Summit Trail fence and the management cabin located on the Koʻolau Summit trail near Poamoho Trail. Hawaiian Electric Co. (HECO) power lines also traverse most of the Koʻolau Mountains and can have significant social and environmental impacts. Plans for the Waʻahila Ridge project, for example, have been opposed by groups such as Mālama O Mānoa, The Outdoor Circle and Life of the Land, which contend that the construction of taller poles will destroy the scenic beauty of the area, disrupt native plants and birds and perhaps even precipitate landslides on the steep valley walls (Leone, 2001b).

The Haʻikū Stairs, also known as the Haʻikū Ladder or Stairway to Heaven, is another high-profile feature in the Koʻolau range. Ascending to Puʻu Keahiakahoe at the summit, the Stairs are a series of galvanized-steel ship ladders totaling 3,922 steps that were linked together in 1955 to give access to microwave transmission facilities. During World War II, it served to provide access to the two now-abandoned buildings on the top of the ridge. The Stairs have been popular with hikers; at the peak of its popularity in 1982 an overwhelming 1,000 hikers a month swarmed the ladder. Vandalism, trespassing, vegetation damage and littering have been some of the problems associated with the high visitor load (FHS, 2001). Although currently closed, repairs of the Stairs are scheduled for completion by October 2002 (CCH, 2001).

Roads and entryways leading into the KMW watershed area are well known (See **Overlay E: Recreational Use and Resources)**. Roads provide the same benefits and problems that trails do, except often on a greater physical scale. The steep cliffs on the windward side do not really allow much access in terms of roads, except near Lāiʻe and Hauʻula. Access roads into the watershed are concentrated and most trafficked in the Greater Honolulu Area. Little public access exists from the northern leeward portions of the watershed. One of the most important accessways into the area for management purposes may be the Kīpapa trail, which is the main access route for the Oʻahu Forest National Wildlife Refuge.

III. Threats to the Koʻolau Mountains Watershed

Chapter III outlines the extent and severity of the threats to the Koʻolau Mountains' resources to gain a better understanding of the primary management challenges. The primary threats discussed herein include invasive non-native plant species, feral ungulates and other non-native animals, human disturbances, aquatic pollutants and wildfire.

A. Invasive Non-Native Plant Species

The problem of alien species invasion in native habitats is a well-documented management problem in Hawaii's natural areas. Some alien plants outcompete native species for space, light, water, and nutrients, and are capable of quickly converting native ecosystems to alien-dominated vegetation. It is believed that invasive non-native plant species can also alter soil moisture, water, nutrient and fire regimes, and diminish habitat for native animals that rely on native vegetation (Smith, 1985). By reducing the structural complexity of the forest, alien species generally decrease the effectiveness of vegetation to uphold its watershed functions.

Although weeds can displace economically or culturally important native plants and convert beautiful forest areas into impassable, thorny tangles, not all non-native plants are invasive. Many beneficial non-native plants have been introduced to Hawaiʻi. In the last 200 years, of the over 4,600 plant species that have been introduced to Hawaiʻi, only 86 have established themselves as known pests (Smith, 1985). Species that can be particularly threatening to watersheds have several characteristics:

- poor rooting systems, which increase the potential for inadequate groundcover and severe erosion,
- high fire threat (i.e. broomsedge [*Andropogon virginicus*])
- high potential to modify habitat by creating dense stands (i.e. strawberry guava) or shading out other plans (i.e. purple velvet leaf [*Miconia calvescens*])

It is estimated that 20 to 50 new non-native species arrive in Hawaiʻi every year (Loope and Canfield, 2000), mostly via aircraft, ship cargo, or mail (CGAPS, 2001). Many non-native species may have been escaping from botanical gardens, such as Lyon and Hoʻomaluhia, which directly abut forested areas (KMWP, 2002). Gerrish and Mueller-Dombois (1980) found some support for this hypothesis, finding that an area close to a metropolitan area (Tantalus) contained more weeds than a more remote area (Pūpūkea). Juniper berry (*Citharexylum caudatum*) and several other plants which now infest the southern Koʻolau Range appear to have dispersed from the Lyon Arboretum (Smith, 1985).

On Oʻahu, the Hawaiʻi Ecosystems at Risk Project (HEAR) has identified the pest species broomsedge, *Clidemia*, lantana (*Lantana camara*), *koa haole* (*Leucaena leucocephala*), molasses grass (*Melinis minutiflora*), kikuyu grass (*Pennisetum clandestinum*), strawberry guava, prickly Florida blackberry (*Rubus argutus*), and Christmas berry to be widespread and very difficult to eradicate. One of the most serious of alien plants, *Clidemia* has become one of the dominant understory plants in the Koʻolau Mountains (Sohmer and Gustafson, 1987).

Other established pest species that are ubiquitous or problematic in the watershed include: narrow-leaved carpet grass (*Axonopus fissifolius*), common guava (*Psidium guajava*), kahili ginger (*Hedychium gardnerianum*), *Triumphetta semitriloba*, common ironwood (*Casuarina glauca*), *manuka* (*Leptospermum scoparium*), Guinea grass (*Panicum maximum*), and *Pterolepis glomerata*.

In contrast to established species are incipients, which are those species that are present but where control and eradication are still possible. For example, *Miconia* has been known to exist in the Koʻolau range for some time, but ongoing patrols have been able prevent it from proliferating in the same manner that it has on Maui and Hawaiʻi. New seedlings are still being found, and recent populations and parent trees have been cleared in areas such as Mānoa. HEAR also identified the faya tree (*Myrica faya*) and fountain grass (*Pennisetum setaceum*) as incipient species. *Ficus* spp. are spreading into valleys such as Kuliʻouʻou and pose a future threat to the central Koʻolau Mountains (Gagne, pers. com., 2001). Glorybush or cane ti (*Tibouchina herbacea*) although not on Oʻahu yet, is an imminent threat (KMWP, 2002). A cane ti relative, *T. urvilliana* has been seen seeding in the upper Koʻolau Mountains, and may be threatening as well (Kawelo, pers. com., 2002).

The Oʻahu Invasive Species Committee (OISC) developed a list of species (both plant and animal) that potentially warrant special attention. These include *Miconia*, fountain grass, frogs (*Rana catesbeiana*, *Eleutherodactylus coqui*), thorny *kiawe* (*Prosopis* spp.), Himalayan blackberry (*Rubus discolor*), parrots (*Aratinga mitrata*, *Psittacula krameri*), fern tree (*Filicium decipiens*), *manuka*, *Hiptage benghalensis*, fireweed (*Senecio madagascariensis*), downy rose-myrtle (*Rhodomyrtus tomentosa*), kariba weed (*Salvinia molesta*) and fiddlewood (*Citharexylum spinosum*). OISC is in the process of developing a GIS database, and has thus far included information on a few species such as *Miconia*, fountain grass and thorny *kiawe*. Some of the most problematic alien plant species are profiled in Appendix B.

B. Feral Ungulates [17]

Prior to the arrival of humans, the hoary bat and monk seal were the only mammals in Hawaiʻi. For millions of years, native forests evolved in isolation, away from grazing or browsing animals, consequently losing their need for defenses such as thorns or poisonous sap. When the Polynesians first came to Hawaiʻi, they brought along the relatively small (20 kg.) Polynesian pig. Recent archaeological studies suggest that the early Hawaiians kept their carefully tended pigs close to their homes, preventing them from running loose in the forest (Loope, 2001). The feral pigs that now roam Hawaii's forests and wreak havoc on the native plants and animals are of a different breed – an interbred variety between the larger European pig (up to 200 kg.) and the Polynesian breed. Bones of these pigs do not appear in the pre-Captain Cook sinkhole strata.

When these pigs were finally released or escaped into Hawaiian forests, they encountered no natural predators and found an ample supply of food. Scientific research on feral animals

[17] **Feral** refers to domesticated animals that have adapted to living in the wild. **Ungulates** are hoofed mammals that are usually adapted for running. Most are large herbivores, including pigs, deer, goats and cattle, as well as gazelles, horses and elephants.

conducted in the 1970s and 1980s was overwhelmingly conclusive of their deleterious impacts on the environment. The general effects of pig feeding and predation on the resources of the watershed are manifold and have been well documented. Cory (2000) provides a good summary of the scientific literature on the effects of pigs in native Hawaiian ecosystems. Harmful ungulate activity includes:

- Destroying native habitat through trampling, eating, and rooting;
- Creating soil disturbance, accelerating degradation, erosion, landslides and sedimentation, thereby decreasing infiltration rates and groundwater recharge and affecting stream habitat quality;
- Encouraging the spread of alien plant taxa that are better able to exploit newly tilled soils than are native taxa;
- Spreading the seeds of invasive species such as strawberry guava and Christmas berry;
- Direct predation on native species such as tree ferns (*Cibotium* spp.), other succulent-stemmed plants, and invertebrate species;
- Acting as vectors for human diseases, including coliform bacteria and *Leptospira* in surface waters;
- Disturbing archeological sites by knocking over stone walls, tilling soil and otherwise modifying the landscape; and
- Creating wallows, which serve as breeding grounds for mosquitoes, a vector for avian malaria and other diseases.

Feral pigs (*Sus scrofa*) have been known to be in the Koʻolau Mountains for about 165 years, and are presently responsible for much of the disturbance and wet forest modification in the Koʻolau Mountains, as a high percentage of soil is bare in regions inhabited by pigs (Stone 1985; Roumasset, et al., 1997).[18] Pig distribution data is currently patchy, but the consensus is that pigs are ubiquitously distributed throughout much of the Koʻolau range, inhabiting all native and non-native ecosystems except the wet cliff areas (HINHP, 2000; Roumasset, et al., 1997). Since the majority of hunting activity is conducted within State-managed hunting areas, pigs may be more highly concentrated in private lands, especially those adjacent to the hunting areas, as pigs tend to use these as a refuge from hunting pressure. Pigs are also known to be in healthy numbers at Kualoa, at the back of Waimānalo (KMWP, 2002).

Hunting and fencing isolated parts of the watershed has curbed recent levels of pig damage, but even a single pig is capable of eliminating a rare plant species during one feeding. Since they reproduce at very high rates, 70% of the population must be removed annually to reduce pig numbers over the long term. Goats can be found in Puʻu Kanehoalani and Makapuʻu, although the Koʻolau Mountains are generally not favored goat habitat (Kawelo, pers. com., 2001).

C. Other Non-Native Animals

Smaller animals also have the potential to become serious pests in the Koʻolau watershed. Although the impacts of non-native small mammals on the watershed are poorly understood, biologists generally agree that they represent threats to native species. Like ungulates, small

[18] In areas inhabited by pigs, as much as 88% of the soil has been found to be bare in Hawaiʻi (Kurdila, 1995).

mammals can also affect water quality by serving as vectors of water-borne diseases such as Leptospirosis and Cryptosporidiosis.

Rats in particular have been recorded as being particularly destructive to many rare species. At all elevations, rats prey on native bird eggs, nestlings, and especially on O‘ahu, native land snails. Nest predation by rats is thought to be the primary reason for low reproductive success in the O‘ahu *‘elepaio* (USFWS, 2001). Rats are also known to eat the fruits of native *loulu* palms and lobelias and strip the bark of some native plants (Cuddihy and Stone 1990; USFWS, 2000). According to Katie Swift, Fish and Wildlife biologist who specializes in pest control, no one knows the exact population of rats, but they are known to exist throughout the Ko‘olau Mountains range and are believed to be a significant problem (Leone, 2001a). These aliens include both the Polynesian rat, whose forebears probably hitched a ride on the first sailing canoes, and the black and Norway rats, which followed years later by stowing away on European or American vessels.

In addition to rats, other species such as mongoose, feral cats, dogs, house mouse, and certain non-native birds are known to consume or compete with native species. Cats, which prey on native birds and can transmit toxoplasmosis to native birds, have been recently estimated to number around 80,000 on O‘ahu (Staples and Cowie, 2001).

There are several non-native invertebrate pest species as well. Slugs (*Milax gagates*, *Limax maximus*, *Veronicella* spp.) consume fruit from native plants and prey on seedlings and mature plants. The two-spotted leafhopper (*Sophonia rufofascia*) is a major concern for the *uluhe* fern, which is particularly sensitive to leafhopper feeding. Large patches of *uluhe* have been dying on the hillsides of Mānoa and Pālolo Valleys, ‘Aiea, and Maunawili since 1990. The reaction of the *uluhe* is a major cause of concern because *uluhe* covers a large portion of the watershed and damaged areas do not appear to grow back, becoming susceptible to erosion and alien weed invasion. Another invertebrate, the black twig borer, burrows into branches and propagates a pathogenic fungus that kills its host (Burt, et al., 2000). Mosquitoes (*Aedes albopictus* and *Culex quinquefasciatus*) transmit deadly diseases to native birds, and can also be vectors for human diseases as well. One of the main causes of reduced adult survival of the endangered O‘ahu *‘elepaio* is disease, particularly avian pox and avian malaria, which are carried by the introduced southern house mosquito (*Culex* spp.) (USFWS, 2001). Non-native cannibal snails (*Euglandia rosea*) are also a serious threat that has decimated rare and endangered populations of native *Achatinella* tree snails on O‘ahu (HINHP, 2000).

D. Human Activities

Any human activity, even seemingly innocuous practices such as birdwatching or beneficial management actions such as fence building can be destructive if improperly performed. Humans can damage vegetation directly through trampling or overcollection, and sometimes indirectly by providing the ignition source for fire or introducing weeds. Ordnance training on military lands has the potential to cause wildfire in forested areas and may increase erosion and the spread of noxious weeds. As mentioned in the recreation section, human beings can also increase the likelihood of plant pest introductions; in fact, human traffic has been implicated as a major culprit in the spread of such major pests as *Clidemia*.

In terms of sheer numbers hiking is the highest impact human activity in the KMW area and has the potential to be detrimental. According to one survey (Donoho, et al., 2001), 78% of hikers are visitors to the State of Hawai‘i. The proximity of the Ko‘olau Mountains to Waikīkī allows many of the trails within the watershed area to be readily accessed, subjecting them to high visitor loads. For example, in 2001 commercial venture permitting for Mānoa Falls Trail needed to be restricted since the provision of permits to all applicants would have ballooned visitor loads to 100 patrons per day, while the commercial capacity established for Mānoa Falls is set only at 24 (Coloma-Agaran, 2001). In addition to Mānoa, several other trails experience a fair amount of visitor traffic. Some of these were targeted for potential survey in a trail analysis conducted in 2001 (Donoho, et al., 2001), which included visitor traffic loads as one criterion in the selection process. These trails, with their use characterization in parentheses, were Maunawili Falls (moderate use), Pali Lookout (extremely high use), Tantalus Mauka system (moderate to high use), Maunawili (high use for first 2 miles), Wiliwilinui, Kuli‘ou‘ou, and Hawai‘iloa Ridge (moderate use).

Motorized vehicle recreation can also be a significant source of damage in the watershed, causing erosion and facilitating the colonization of weeds by exposing bare soil. Sanctioned motorcross racing occurs in the Kahuku Training Area near Poamoho, but increased motorcross popularity has led to trespassing onto other areas. Fences and other barriers have proved to be ineffective against these transgressions (INRMP, 2001).

Native plant collection occurs within the watershed area, but is primarily restricted to seeds, and is mainly conducted through Lyon Arboretum and its cooperators (Gagne, pers. com., 2002). *Palapalai* (*Microlepia strigosa*), in addition to *‘ōhi‘a* and other plants are also gathered by various *hula halau* in areas of the watershed. This practice however, has not been catalogued or documented in a comprehensive manner. Subsistence-based collection also occurs in the watershed on small scales, but the prevalence of this practice is also unknown and data mostly anecdotal.

Illicit cultivation of contraband such as marijuana has historically been a concern. In the past, growers set booby traps to protect their valued plants, interfering with field management and threatening the safety of watershed staff or volunteers. Though evidence has not been collected, it is likely that this activity persists today in some areas of the watershed. Another potential threat – illegal dumping of cars, building materials and hazardous materials – also occurs in the Ko‘olau Mountains, documented in areas such as Nu‘uanu/Tantalus and Waimānalo (KMWP, 2002).

E. Aquatic Pollutants

Although the focus of environmental contaminants in a watershed is usually on urban and agricultural settings, the forested areas of the KMW area still have some concerns. The 1998 Hawai‘i Water Quality Assessment conducted by the State Department of Health (CWB, 1998) found that “much of the pollutants contained in runoff originates in the upper watershed areas that have no human induced causes.” Namely, these pollutants occur as siltation, suspended solids, turbidity, nutrients, and pathogens. Most of these problems are related to soil erosion, which is a natural process in forested areas, but also is amplified in residential

interface areas such as Mānoa, Makiki, and Central Oʻahu (KMWP, 2002). Some studies (Roumasset, et al., 1997) have suggested that soil erosion in the Koʻolau Mountains is currently minimal, while acknowledging that the continued presence of feral ungulates, as well as disturbances that increase the rates of soil erosion could change that trend. Other studies however, have suggested that soil erosion as result of pig damage is already a concern in the Koʻolau Mountains.[19] Erosion has also been found to be significant at the H-3 highway construction site in Hālawa (Hill, et al., 1997; Hill, 1996) and around military training areas (KMWP, 2002).

The sediments eroding from forestlands into streams contribute to a high rate of suspended sediments, which are comprised of eroded silts and clays, organic detritus and plankton. High levels of suspended sediment produce a "muddy" appearance in stream waters. These muddy waters affect more than just aesthetics. Suspended sediments can:

- stress native fish like *oʻopu*, and hinder their ability to find food;
- damage the gills of some fish species, causing them to suffocate;
- increase water turbidity, which limits light penetration and impairs photosynthesis for aquatic plants;
- raise water temperatures, which effectively serves as a chemical gauntlet for some migrant aquatic species; or
- lower dissolved oxygen concentrations, which at decreased levels, can kill aquatic vegetation, fish, and bottom dwellers.

Once these sediments finally settle on lake bottoms or streambeds they produce other detrimental impacts. High sedimentation levels can:

- affect levels of nutrients, solids and oxygen-demanding materials;
- indicate the presence of other pollutants such as phosphorus, heavy metals, and some pesticides;
- eliminate essential habitat and bury food sources and spawning sites for stream life;
- smother bottom-dwelling organisms *ʻōpaʻe* and periphyton (the algae attached to bottom vegetation and rock surfaces);
- reduce the capacity of stream channels to carry water and of reservoirs to hold water.

These sediments often contain a number of inorganic compounds, such as barium, chromium and copper, which may naturally occur in groundwater from the erosion of natural deposits. The main concern in the Koʻolau Range however, is nutrient loading for nitrogen and phosphorus. Excessive nutrient levels in water bodies can stimulate algal blooms. Large blooms limit light penetration into the water column, increase turbidity, and increase biological oxygen demand, resulting in reduced dissolved oxygen levels. This process, termed eutrophication, drastically affects aquatic organisms by depleting the oxygen these organisms need to survive. Nitrates can also be a cause for human health concerns. According to the EPA, sources of nitrates may be fertilizer runoff, leaching from cesspools, septic tanks, sewage, or erosion of natural deposits. A sudden removal of large quantities of

[19] Buck, et al. (1988) found that 27% of 37 field plots in a DLNR sample in the Koʻolau Range contained slight surface erosion on steep slopes, while over half of the plots showing erosion had signs of impact by feral pigs or cattle.

vegetation, such as through harvesting or fire, increases leaching of nutrients from the soil into surface and ground waters (Likens, et al., 1970).

There are currently two Water Quality Limited Segments[20] within the KMW area where pollutants were attributed to natural sources (CWB, 2000). Kahana Bay pollutants include suspended solids and turbidity, while the Ala Wai Watershed and Canal contains nutrients, pathogens, metals, turbidity, and suspended solids, although sources in the Ala Wai were deemed to be of both natural and urban origin. The subsequently published Ala Wai Total Maximum Daily Load[21] report determined that approximately 60% of the nitrogen and phosphorus that is negatively affecting the Ala Wai is coming from the conservation district lands *mauka* of the canal, with the source of this nutrient pulse being decaying biomass (USEPA and HDOH, 2001).

Toxins and Bacteria

Pesticide use in the upper watershed has not been labeled as a concern yet. In tests for organochlorine pesticides, a survey of six KMW area streams[22] found that conservation area stream reaches did not contain any detectable levels of contaminants (Brasher and Anthony, 2000). High levels of pesticide were found in specimens collected at the urban and mix-land use sites. Swimming in the streams could result in Leptospirosis, a potentially fatal illness caused by a water-borne bacterium spread by feral ungulates and rats. The State Department of Health however, does not currently conduct any regular monitoring of stream pathogens.

In March 1999, USGS' O'ahu NAWQA (National Water Quality Assessment) study team began a two-year water-column study at three locations: Waihe'e, Mānoa and Waikele Streams (USGS, 2001a). All sites were sampled for major ions, nutrients, dissolved organic carbon, suspended organic carbon, and suspended sediment. At 6 other intensive fixed sites, samples were analyzed for trace elements and pesticides. A continuous record of discharge, specific conductance, and water temperature was also measured at all sites. While the analysis of these results have not been compiled yet, once available, this data will provide a good benchmark for the water quality and pollutant monitoring in the Ko'olau Mountains.

F. Wildfire

Because Hawaii's flora has evolved with infrequent, naturally occurring episodes of fire (lava flows, infrequent lightning strikes), most native species are not fire-adapted and are unable to recover well after recurrent anthropogenic fires. Alien plants, particularly grasses, are often more fire-adapted than native taxa and will quickly exploit suitable habitat after a fire, gradually encroaching further upslope into native vegetation (Cuddihy and Stone 1990).

[20] Water Quality-Limited Segments are water bodies which, without additional action to control nonpoint sources of pollution, cannot reasonably be expected to attain or maintain State Water Quality Standards. Water quality data obtained historically in these areas has exceeded standards in one or all of the following parameters: (Total Nitrogen, Ammonia Nitrogen, Nitrate and Nitrite, Total Phosphorus, Light Extinction, Chlorophyll-a, and Turbidity)

[21] TMDLs, or Total Maximum Daily Loads, are a determination of how much of a certain pollutant a water body can assimilate and still meet waters quality standards.

[22] The selected streams were Mānoa, Nu'uanu, Kāne'ohe, Waikele, Poamoho and Waihe'e.

Fires cause the removal of vegetation cover, loss of the soil-anchor feature of root masses, and exposure of bare mineral soil. This combination disposes burned areas to high levels of erosion. The effects of suppression efforts and equipment operations necessary to control fire can magnify the erosion problem (DoFAW, 2001a), although suppression activity of this type is often difficult in the upper Koʻolau range, since many areas are only helicopter-accessible. A large fire would also likely reduce evapotranspiration and significantly increase runoff. Heat levels can also reduce permeability of soils and reduce recharge levels. In general, the higher the intensity of the fire, the more drastic the anticipated impacts (Roumasset, 1997).

The Koʻolau Mountains currently have a limited, standardized system for tracking fire location and frequency. However, from 1980-1995, approximately 8 to 10 fires occurred in the conservation zone under the jurisdiction of the DoFAW in the low elevation slopes of the Koʻolau Mountains (USFWS, 1998; USFWS, 1996). Fire risk, or the potential for fire, is contingent on frequency of human activity and climatic conditions. The wildland-urban and wildland-military training area interfaces, power lines and camping sites are important factors as ignition sources. Climatic conditions are often related to seasonal rainfall, where the dry summer months and brisk winds can lead to high-risk fire conditions (USFWS, 1998). Wildfire hazard, describing the fire intensity, depends upon topography and fuel source. In general, the southern Koʻolau range and Pūpūkea in the far northern area are drier and more susceptible to fire. In central Oʻahu, Waiawa also has a high frequency of fires. A fire susceptibility rating can be developed when these data are collected and compiled into a fire danger rating system.

G. Urbanization and Development

Urban development and road construction have large potential to negatively affect the water quality and quantity of the watershed. Urbanization can cause a decrease in soil permeability and infiltration rates, thereby reducing groundwater recharge and increasing runoff (Shade and Nichols, 1996). It also often involves the removal of vegetation cover, disturbance and soil compaction, leading to increases in sedimentation.[23] Construction enhances the transport system for sediments, increasing the damage from existing and additional sedimentation.

The potential for these threats in the KMW area is low, since the area is currently zoned as conservation district. Most of the district is privately owned, so changes in zoning could significantly increase the probability of these threats. Urban creep along valley sides could also become possible through easements and permits.

[23] Highway (H-3) construction increased suspended sediment loads by 56 to 76 percent from 1983–91 in North Hālawa, Haʻikū, and Kamoʻoaliʻi Drainage Basins (1 to 4 sq. mi. basins) (Hill, 1996).

IV. Overview of Existing and Current Management Programs

This section will provide an overview of the existing management programs conducted within the KMW area to gain an understanding of the activities that are already in progress. The existing context for management is important to understand as the proposed management actions are built upon the pre-existing foundation of management programs that have been conducted in the Koʻolau Mountains and throughout other watershed partnerships in Hawaiʻi.

The partners of the KMWP are alphabetically listed below, with each watershed partner profiled to describe the objectives of the partner, management activities, resources available and property owned. Subsequently, the adjunct partners are also profiled, with mention of their management activities and possible contribution in terms of expertise in watershed management. This section can provide partners information regarding prospective resources for future projects as well as highlight possible programming gaps.

State of Hawaiʻi Agribusiness Development Corporation (ADC)

The Agribusiness Development Corporation was formed in 1994 to facilitate and provide direction for the transition of Hawaii's agriculture industry from a dominance of sugar and pineapple to one composed of a diversity of different crops. The stated goal or mission of the ADC is to make optimal use of the State's agricultural assets for the economic, environmental, and social benefit of the people of Hawaiʻi by facilitating the transition of agricultural infrastructure from plantation operations into other agricultural enterprises; by carrying on marketing analyses to direct agricultural industry evolution; and by providing leadership for the development, financing, improvement, and enhancement of agricultural enterprises. One of the ADC's first major projects was the purchase of the Waiāhole Ditch in 1999. The ADC also administers an area about 590 acres along the windward cliffs in Waikāne, although with its focus on agricultural lands and irrigation systems, the area is currently unmanaged. ADC does however manage some lands at Kekaha, Kauaʻi, and will have a project soon on the Big Island.

U.S. Army

The U.S. Army is committed to environmental stewardship as an integral part of fulfilling its mission. The ecosystem management program on Oʻahu has a commitment to preserve, protect and enhance natural and cultural resources and lands upon which the quality of training ultimately depends. The primary document that guides the Army's natural resources management is the Integrated Natural Resources Management Plan (INRMP), which was required by the Sikes Act for each military installation with significant natural resources.

The U.S. Army owns two areas within the KMWP area: Kahuku Training Area (KTA) and Schofield Barracks Military Reservation – East Range (SBMR), totaling about 7,100 acres. KTA in the northern Koʻolau Mountains is primarily used for tactical maneuver and warfare training, while SMBR's East Range on the leeward section of the Koʻolau Mountains is used to conduct foot maneuvers and paradrop exercises. The U.S. Army also manages a third

property, the Kawailoa Training Area (KLOA), which, located on the western slopes of the range hosts patrol, helicopter, unit tactical and jungle warfare training.

Natural resource management activities differ by training area. On KTA, the Army engages in incipient weed control of species such as *Melochia umbellata* and fountain grass, and control of established weeds around such rare plant populations as *Eugenia koolauensis*. Activities in KLOA focus on the protection of pristine habitat through fencing projects like that at ʻŌpaeʻula, rare species management and monitoring, ungulate control and weed control of species such as *manuka* and strawberry guava. SMBR activities focus on invasive ginger and ungulate control and rare species monitoring.

In the KLOA portion of the Koʻolau Mountains, the U.S. Army has banded together with Kamehameha Schools (the landowner), the U.S. Fish and Wildlife Service, and the State Division of Forestry and Wildlife to demonstrate the advantages of the KMWP. The parties formed a task group to undertake fencing of a 150-acre area of the ʻŌpaeʻula watershed to protect a sensitive native ecosystem from feral ungulate threat. The pilot project provided baseline information and regulatory protocols to gauge future watershed work in the Koʻolau Mountains.

U.S. Fish and Wildlife Service (USFWS)

The mission of the USFWS is to work with others to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. This statement acknowledges that working cooperatively with partner organizations, private landowners and local communities is the best way to approach long-term conservation. The USFWS has a number of programs designed to provide technical assistance, coordination and cost-share funding for conservation projects. Additionally, the USFWS directly manages lands of the National Wildlife Refuge System. Oʻahu Forest National Wildlife Refuge was established in December of 2000 on land formerly owned by Castle and Cooke. The 4,525-acre refuge is located on the leeward slopes of the northern Koʻolau Mountains, just south of the Schofield Barracks Military Reserve. The management of this property is still in its infancy, but staff at the Oʻahu National Wildlife Refuge Complex have an Conceptual Management Plan that focuses on the management of native natural communities, endangered and threatened species, public use for awareness and appreciation, and the protection and management of significant cultural and historic resources.

City and County of Honolulu Board of Water Supply (BWS)

The Board of Water Supply is a semi-autonomous agency of the City and County of Honolulu. Its primary function is to provide municipal water supply to meet the domestic needs and fire protection for the island of Oʻahu. The BWS's Integrated Resource Plan emphasizes the importance of coordinating technical expertise and working with other agencies and the public. Since 1929, the BWS has been monitoring the integrity and quality of the island's public water supply, testing water for clarity, physical properties, mineral content, trace metals, nutrients, chemical contaminants and bacteriological quality and integrity. This testing program is conducted in cooperation with the State of Hawaiʻi Department of Health (DOH), which performs all regulatory monitoring of drinking water in Hawaiʻi. The BWS also has a number of educational programs to inform the public about

Oahu's municipal water resources. The City and County of Honolulu owns several scattered properties totaling nearly 4,900 acres throughout the southern portions of the watershed area. These properties were acquired and preserved because they represented important water resources. However, there has not been much active management of these areas. BWS has recently become involved with community-based development and watershed management partnerships such as the *Mohala i ka Wai* project in Wai'anae.

Tiana Partners, et al.

Tiana Partners, et al. owns a section of land of nearly 300 acres in the southern end of the watershed. Kamehameha the Great conveyed the *ahupua'a* of Niu to Alexander Adams, his ship captain and harbormaster in the early 1800s. The ahupua'a consisted of about 2,000 acres and has since been divided between family members. Currently the land is the home of three generations of Captain Adams' descendants. Tiana Partners does not do much in the way of management other than weeding ivy gourd (*Coccinia grandis*) and kikania (*Datura stramonium*).

Kamehameha Schools

Kamehameha Schools was established in 1884 under the will of Bernice Pauahi Bishop. Its mission is to fulfill Pauahi's desire to create educational opportunities in perpetuity to improve the capability and well being of people of Hawaiian ancestry. One of the important goals of its 2000-2015 Strategic Plan is to *mālama i ka 'aina*, or practice ethical, prudent and culturally appropriate stewardship of lands and resources. Kamehameha Schools seeks to actualize this goal by both managing lands to protect and enhance ecosystems and the *wahi kupuna* (ancestral sites inclusive of all cultural resources and *iwi* [bones of the dead]) they contain, integrating Hawaiian cultural values and knowledge into resource stewardship practices, and promoting a broad understanding of stewardship efforts and, as appropriate, cultural resource management programs. Although Kamehameha Schools' strengths in natural resource management are in cultural stewardship and education, its resources are diverse. The Land Assets Division of the Endowment Group at Kamehameha Schools manages 26,000 acres of land in nine discontiguous parcels within the KMW area. Kamehameha Schools has already collaborated with other partners in completing the aforementioned 'Ōpae'ula fencing project (see U.S. Army section). Other fencing projects are in the planning stages.

Dole Foods Co., Inc.

Dole Foods Co., Inc. is the owner of a US military-managed 5000+ acre parcel of land in the northern Ko'olau Mountains adjacent to the Kahuku Forest Reserve. Although they are not the active managers of this land, Dole has a socially and environmentally responsible corporate philosophy. Its emphasis is on preventing adverse impacts of their operations on the environment, conserving resources and reducing waste, and preventing accidents and illness and protecting human health and safety. Environmental stewardship is an integral part of Dole's concept of quality. Dole has people with environmental and technical expertise in their operations worldwide who are responsible for environmental protection efforts. Many of these programs are in active partnership with local communities and governments. Dole has an expertise in Integrated Pest Management (IPM), with a comprehensive research program for biological control agents (naturally occurring organisms that control pests and diseases).

In many parts of the world, Dole provides support and services such as drinking water, electric power, flood control, transportation and roads for its employees and their communities. They have provided training and education on recycling, composting, water conservation, erosion prevention and reforestation.

Bishop Museum (BM)

In addition to ownership of a 587-acre property in the Kalauao Valley of the south central Koʻolau range, the Bishop Museum has distinct interests in both ecology and culture. BM houses the Hawaiʻi Biological Survey (HBS), which was established by the State Legislature in 1992. This ongoing natural history inventory of the Hawaiian Islands was created to locate, identify and evaluate all native and non-native species of flora and fauna within the state and maintain the reference collections of that flora and fauna for a wide range of uses. HBS gathers, analyzes, and disseminates the biological information necessary for the wise stewardship of Hawaii's biological resources. The HBS will conduct a coordinated inventory and monitoring program to assess the overall status and trends in the abundance, health, and distribution of plants and animals, as well as the ecosystems upon which they depend. BM also has a strong interest in the conservation of cultural resources. The Department of Anthropology offers services integral to the completion of archaeological reports, with expertise in such areas as archaeological inventory survey, data recovery excavations, historical archaeology, lithic analysis, paleoethnobotany and zooarchaeology.

Department of Hawaiian Home Lands (DHHL)

The mission of the DHHL is to manage the Hawaiian Home Lands trust effectively, and to develop and deliver land to native Hawaiians. The Waimānalo cliff parcel is located within the boundaries of the KMWP area. This land is not suitable for development and is not actively managed.

Manana Valley Farm, LLC (MVF)

The property within the KMWP boundary owned by Manana Valley Farm, LLC, was purchased by MVF from a Japanese corporation in 1999. Prior to and since that time, there has not been any active management of this particular property. The property is a strip of land on the leeward side of the Koʻolau Mountains, along Manana and Waimano valleys, totaling nearly 1,400 acres in size. Currently, MVF has no specific management goals for the property, nor does it have many internal resources. Among the opportunities MVF is exploring is the participation in management activities within the KMWP with other partners.

Queen Emma Foundation (QEF)

The Queen Emma Foundation is a non-profit organization whose mission is to support and advance health care in Hawaiʻi, primarily through The Queen's Medical Center. QEF accomplishes this by managing and enhancing the income-generating potential of the lands left to The Queen's Hospital by Queen Emma in 1885, as well as other properties owned by Queen Emma Foundation. Revenues from these lands are used to support and advance health care in Hawaiʻi. The income generating areas of the QEF lands are mostly in the *makai,* or seaward areas, but QEF does own a *mauka* tract of land in Hālawa of approximately 1,100 acres in size. Although staffing concerns limit the amount of natural resource management

that is done in this area, biological and cultural surveys of this area have been conducted, and volunteer groups have been conducting weed clearing and restoration projects.

State of Hawai‘i Department of Land and Natural Resources (DLNR)

Division of Forestry and Wildlife (DoFAW)
The State Division of Forestry and Wildlife (DoFAW) is the largest land management agency in Hawai‘i. It owns several properties in the watershed, totaling nearly 25,000 acres. Its Watershed Protection and Management Program ensures viable water yields by protecting and enhancing the condition of Hawaii's forested watersheds to retard rapid run-off of storm flows, prevent and reduce soil erosion, and improve infiltration rates. Its main activities during the fiscal years 1998-2000 have included:

- Prevent and suppress forest and range fires on key watersheds to include forest reserves, public hunting areas, and natural area reserves.
- Cooperate with established fire control agencies for the protection of other wildland not within departmental protection areas to the extent needed to provide for public benefits and environmental protection.
- Control livestock trespass and non-native animals in priority watersheds.
- Survey and control noxious plants, forest insects and diseases that can damage watershed integrity and native ecosystems.
- Plan for and implement the reforestation and management of deteriorating and/or disturbed state watersheds as may be appropriate for watershed value enhancement.
- Promote, encourage, and advocate incentives to encourage the maintenance and enhancement of key watersheds on private lands.
- Review and comment on Environmental Assessments, Environmental Impact Statements, Conservation District Use Application Permits and other Land Use applications.

DoFAW has many other ongoing programs, including:

- Native Resource Protection and Management
- Outdoor Recreation Resources Management and Development
- Forest Products Development
- Public Information and Stewardship

The role of DoFAW in this partnership, like in many others, will be with in-kind services in watershed and other natural resource management activities.

Commission on Water Resource Management (CWRM)
The Commission on Water Resource Management (CWRM) administers the State Water Code, which was created by the 1987 Hawai‘i State Legislature. The CWRM's general mission is to protect and enhance the water resources of the State of Hawai‘i through wise and responsible management. The Water Resource Management division provides administrative, staff, and technical services in support of the CWRM. The division's primary responsibilities are basic data collection and resource assessment, water resource planning, regulation of water development and use, enforcement and technical support services, and protection of instream uses.

Land Division
The Land Division is responsible for managing State-owned ceded lands in ways that will promote the social, environmental and economic well-being of Hawaii's people and for insuring that these lands are used in accordance with the goals, policies and plans of the State. Lands that are not set aside for use by other government agencies come within the direct purview of the division. These lands are made available to the public through fee sales, leases, licenses, grants of easement, rights-of-entry, month-to-month tenancies or kept as open space area.

Division of Aquatic Resources (DAR)
The Division of Aquatic Resources has statutory authority and Public Trust responsibility for the protection, regulation, and management of all living biological resources in state waters, both freshwater and marine. Broad program areas include commercial fisheries and aquaculture, environmental protection, and recreational fisheries. The term "fisheries" applies to all aquatic organisms, for example snails or algae. Activities include projects to assess the status and condition of both nearshore and offshore fish populations and habitats, manage both commercial and recreational populations at levels sustainable for human use, restore depleted populations through targeted enhancement of wild stocks with aquaculture organisms, protect native aquatic species and their associated habitats within an ecosystem context insofar as possible, and provide opportunities for recreational fishing consistent with the interests of the State. Heavy emphasis is placed on the collection of valid scientific information to support the decision-making process.

State Historic Preservation Division (SHPD)
The State Historic Preservation Division of DLNR works to preserve and sustain reminders of earlier times that link the past to the present. SHPD's three branches, History and Culture, Archaeology, and Architecture strive to accomplish this goal through a number of different activities. Reviews of development projects are the primary means of lessening the effects of change on our historic and cultural assets. The division's state Inventory of Historic Properties contains information on more than 38,000 historic sites in Hawai'i. The Burial Sites Program (http://www.hawaii.gov/dlnr/hpd/hpburials.htm), Certified Local Government Program (http://www.hawaii.gov/dlnr/hpd/hpclg.htm), Historic Preserves Program (http://www.hawaii.gov/dlnr/hpd/hppreserves.htm), maintenance of the Hawai'i and National Register of Historic Places (http://www.hawaii.gov/dlnr/hpd/hpregistr.htm), Information and Education Program (http://www.hawaii.gov/dlnr/hpd/hpinfoed.htm) and Inter-Agency Archaeological Services (http://www.hawaii.gov/dlnr/hpd/hpinterag.htm) are all designed to promote the use and maintenance of historic properties for the education, inspiration, pleasure and enrichment of Hawaii's citizens and visitors.

State Parks Division (SPD)
The State Parks Division seeks to govern the use and protection of all lands and historical and natural resources within the State Park System. The outdoor recreation program offers a diversity of coastal and wildland recreational experiences, including picnicking, camping, lodging, ocean swimming, snorkeling, surfing, sunbathing, beach play, fishing, sightseeing, hiking, pleasure walking, and backpacking. The heritage program protects, preserves, and interprets excellent examples of Hawaii's natural and cultural heritage. The exceptional

scenic areas are managed for their aesthetic values while vantage points are developed for their superb views.

United States Environmental Protection Agency (EPA)
USEPA offers a variety of training and assistance programs to support local watershed management efforts. The EPA's Watershed Academy provides technical watershed information and outreach through live training courses, the Internet, and published documents. The EPA has a variety of grant programs that may provide financial support for projects in the KMWP area, including Environmental Justice, Sustainable Development Challenge Grants, Environmental Education and Clean Water Act Grants.

U. S. Forest Service (USFS)
The U. S. Forest Service is represented in Hawai'i by the Institute of Pacific Islands Forestry. Its mission is to develop and disseminate knowledge needed to restore, protect, and sustain forests of the Pacific for purposes of conservation and utilization. To address this broad mission, the Institute is organized into teams to do research on and develop solutions for the challenges facing Pacific Islands forests and to deliver technical and financial assistance to state and private forest lands. Forest Service programs that are available to assist the KMWP include research on the impacts of invasive plants on Hawaiian forests, the distribution of exotic plants in conservation lands, development of biological control agents for high priority weeds, and restoration of Hawaii's indigenous forests. The Forest Service also provides information on the risk assessment of alien plants in Hawai'i and control techniques such invasive plants. Other Forest Service programs pertinent to the KMWP effort include USFS State and private assistance for wildfire prevention and control, technical assistance available for watershed management, reforestation efforts, ecotourism, and cost-share funding programs available for conservation projects.

United States Geological Survey (USGS)
The U.S. Geological Survey (USGS) is known for its impartial data collection and research. The USGS Water Resources Division, in cooperation with local, state, and federal agencies collects streamflow, ground-water level, water-quality, water-use, and rainfall data at sites throughout the State of Hawai'i. Data provided by these networks are fundamental to the quantification, management, and protection of the islands' fragile and finite water resources. Hydrologic data are used to determine the extent and severity of droughts, to identify flood-prone areas and potential hydrologic hazards, to quantify available freshwater resources, to monitor the effects of human activities on water resources, and to resolve complex legal issues associated with water rights.

The USGS Biological Resources Division conducts biological research in the Pacific Basin including the Hawaiian Islands at the Pacific Island Ecosystems Research Center (PIERC). The Center conducts over 45 basic and applied research projects on conservation issues dealing with endangered species and their restoration, and on non-indigenous invasive species (NIS) that create problems for those endangered species and their natural island habitats. The Center conducts research at the ecosystem level as well. All research is primarily to benefit its Department of Interior partners, the Department of Defense, and State agencies that hold large heritage lands that hold these endangered species in trust. PIERC also operates the

Pacific Basin Information Node (PBIN), a new database clearinghouse in partnership with the Hawai‘i Natural Heritage Program (HINHP) at the University of Hawai‘i, which provides georeferencing capabilities for species in their databases, and the Bishop Museum, which serves as a taxonomic authority for these species. PIERC also operates the Pacific Cooperative Study Unit (PCSU), a partnership with the University of Hawai‘i and the National Park Service which serves as a conduit for various agencies to fund conservation research projects and which acts to tie university scientists to those projects.

Hawai‘i State Department of Health (DOH)

The Department of Health is entrusted to protect the health of Hawai‘i residents through the protection of the state’s environment and through regulation of goods, services, and facilities used by the public. It operates through several different programs.

- The Groundwater Protection Program protects groundwater quality by planning and developing groundwater protection strategies, and by working with other county, state, and federal programs. The GWPP is also active in public education and outreach, and the development of community-based workgroups.
- The Water Quality Management Program develops new long-range water quality management plans, and recommends changes and revisions to the existing Water Quality Management Plan for the State of Hawai‘i. Other responsibilities include technical assistance and research toward revising the State’s Water Quality Standards.
- The Clean Water Branch (CWB) protects the public health of residents and tourists who enjoy playing in and around Hawaii’s coastal and inland water resources. The CWB also protects and restores inland and coastal waters for marine flora and fauna. This is accomplished through statewide coastal water surveillance and watershed-based environmental management through a combination of permit issuance, monitoring, enforcement, sponsorship of polluted runoff control projects, and public education.
- The Polluted Runoff Control Program (PRC) works to protect and improve the quality of water resources for enjoyment of and use by the people of Hawai‘i through preventing and reducing nonpoint source pollution, balancing health, environmental, economic and social concerns. The PRC fosters partnerships with other agencies involved in nonpoint source pollution control, promotes community-based watershed management through education and voluntary compliance with environmental management standards, provides federal funding for demonstration of best management practice (BMP) projects from the public and private sectors relating to nonpoint source control, and encourages and supports programs for environmental education.

United States Natural Resources Conservation Service (NRCS)

NRCS, an agency of the US Department of Agriculture, works hand in hand with people and organizations, conservation districts, and other agencies to conserve natural resources primarily on private lands. The mission of the NRCS is to provide leadership in a partnership effort to help people conserve, improve and sustain our natural resources and environment. NRCS has a number of cost-share programs designed to provide technical assistance, coordination and funding for conservation projects. NRCS can contribute to the KMWP in any of these ways.

The Nature Conservancy of Hawai‘i (TNCH)

TNCH is the Hawai‘i program of The Nature Conservancy, an international non-profit organization whose mission is to preserve plants, animals and the natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. TNCH manages preserves throughout the state and is active in watershed partnerships on several islands. Although TNCH does not own or manage lands in the KMW, the O‘ahu Program has been an active partner in the KMWP. Its primary area of focus is Honouliuli Preserve in the Wai‘anae Mountains, which can serve as a working model of integrating natural resources management with community outreach and volunteer involvement. TNCH’s role within the KMWP has been to provide administrative and operational support and technical expertise with regard to building the emerging partnership.

Other large landowners within KMWP include Castle and Cooke, Inc., Hawai‘i Reserves, Inc., Kualoa Ranch, Inc., Samuel M. Damon Trust Estate, Ko‘olau Management Co., Elizabeth Stack, et al., Austin Trust 1971, et al., Hiram L. Fong Jr. Trust, O‘ahu Country Club, and the Roman Catholic Church.

V. Management Activities and Planning Needs

Chapter V outlines the management activities and planning needs for the KMWP. These encompass the areas of threat management, water resources and watershed management, biodiversity protection, cultural resources management, education awareness and public outreach, and administrative coordination and communication.

Generally, the management activities described in this section are common strategies that may be applied to a suite of threats and issues. Where appropriate, site-specific projects have also been mentioned. While the suggested strategies in this chapter will serve as a sturdy template from which the KMWP can develop projects in the future, it is by no means a comprehensive listing, and the rankings and values herein described are not fixed. More projects will undoubtedly develop over the lifespan of this management plan, and the priorities and values of the KMWP will vary over time.

More site-specific projects should be conducted as they are identified, or more rigorously, through a planning process. One example of a process to select site-specific projects was borne out of the 2000 legislative session, during which Act 152 created a Watershed Protection Board and charged it with the development of a State of Hawai‘i Watershed Protection Plan (see DLNR, 2001a). One component of this plan was the development of procedures and criteria for selecting eligible watershed management projects. The plan prescribes that the Ko‘olau Mountains first be broken down to smaller management units. One potential management subdivision is the State Water Resources Protection Plan’s water management area or aquifer system.[24] Using this approach, the CWRM’s database on sustainable yields, permitted uses, rainfall, stream flow and stream assessments can be applied and utilized as criteria to locate prospective projects.

Another potential management unit is subwatersheds. While this selection process is more objective, it is also extremely data intensive, as in many cases the data are limited, dispersed and otherwise unavailable. Intensive ground survey work is needed at the subwatershed level to add more specificity and allow a prioritized ranking to identify the significance of each subwatershed management area.

Another technique for project selection is the Site Conservation Planning Process, widely utilized by The Nature Conservancy. This method employs the 5-S Framework, which identifies Systems, Stresses, Sources, Strategies, and Success measures through a well-tested, scientific process. This process can also be used to update the management plan at a later date and fine- tune targets, threats, and strategies (TNC, 2000). It is recommended that the KMWP use this process to adopt, modify or develop its own strategy for selection of projects given individual landowner needs, desires and resources.

[24] These units include: Wai‘alae East and West, Pālolo, Nu‘uanu, Kalihi, Moanalua, Waimalu, Waipahu-Waiawa, Wahiawā, Waialua, Kawailoa, Ko‘olauloa, Kahana, Ko‘olaupoko and Waimānalo.

This management plan has evaluated each management strategy in terms of its *benefit* to the watershed/partnership, rating each project as either:

++++ = Very High +++ = High ++ = Medium, or + = Low

Benefits assessed a strategy's expected result with respect to the following questions/criteria in mind:

- Will the project's completion help KMWP meet the management goal?
- Will it effectively abate critical threats or develop opportunities and build support for conservation?
- Can it serve as a catalyst for other high-impact future actions?

The strategies were first reviewed, modified and expounded upon by a panel of field experts and land managers. In order to gain a representative assessment of the benefits of each strategy, the ratings were subsequently opened to subjective comment by all partners. This feedback has been synthesized into the benefits ratings presented herein. While strategies sometimes overlap and meet several objectives, there are six basic sections addressed in this section:

1) Threat Management,
2) Water Resources and Watershed Management,
3) Biodiversity Protection,
4) Cultural Resources Management,
5) Education Awareness and Public Outreach, and
6) Administrative Coordination and Communication.

Each section contains a statement regarding the general approach and focus of the management program, the goal of the management program, a matrix of potential strategies to achieve that goal, and further explication of those strategies, where necessary. Projects included in the 2002-2003 Action Plan are checkmarked in the last column.

A. Threat Management

The management goals and strategies for each threat will be addressed separately in the sections to follow. Primary threats covered in this management plan include, in no particular order: 1) Invasive Non-Native Plant Species, 2) Feral Ungulates, 3) Other Non-Native Animals, 4) Human Activities, 5) Environmental Contaminants, and 6) Wildfire.

1. Invasive Non-Native Plant Species

The focus of the Invasive Non-Native Plant Species Program will be on incipient species and prevention. Incipient weeds, such as *Miconia* in the Koʻolau Mountains, exist in a small area and have not yet become established throughout the whole Range. These species should be tackled first because they have a high potential for eradication. Habitat modifying weeds, such as fountain grass, *Miconia* and *Leptospermum* should be given high priority. Control will be achieved via prevention – first preventing new weeds from entering the watershed area, and by eliminating known populations of incipient weed species. Prevention can take

the form of legislation, via stricter import regulations or screening processes, although these strategies are not the primary objectives of the KMWP.

Widespread species, for which the probability of eradication is lower, should be addressed when they threaten relatively intact native forest areas. Other criteria to consider when addressing established invasive plant species could include availability of scientific knowledge, resources of KMWP, and difficulty in controlling the species.

Management Goal:
The management goal for the alien plant control program is to prevent the establishment of incipient alien plants into intact native ecosystems of the Koʻolau Mountains and control established invasive plants where they threaten native forests.

Recommended Actions	**Benefits**	**Yrs. 1-2**
Initiate a control strategy for priority weed species in the watershed using a variety of management techniques, and support the Oʻahu Invasive Species Committee[25] (OISC) on projects that target KMW Area invasive weeds.	++++	✔
Develop and implement a weed control efficacy-monitoring program, including follow-up monitoring with clear methods to determine the effectiveness of control efforts.	+++	✔
Work with botanical gardens, the green industry and DOA to address the spread of invasive weed species.	+++	✔
Survey unknown priority areas for weed species, focusing on areas of rich resource value with high potential for weed introduction (proximity to roads, trails and landing zones). Continue mapping priority alien plant species distribution.	+++	✔
Develop a "Weed Watch" public information/extension program that informs the public of target weeds, identification methods, reporting protocol for new infestations, and contingency plans for quick removal of reported infestations.	+++	
Work with landowners to maintain and support existing weed control programs and target known infestations.	++	

There is no easy formula for controlling alien plants in the Koʻolau Mountains. Each species has to be managed on its own and generally by a number of different approaches. Control solutions are thought to be possible for most plants; it is simply the successful integration of these different approaches that is the challenge to the research scientist and the manager (Smith, 1985). Methods of control include mechanical, chemical and biological. These are briefly discussed below.

[25] Oʻahu Invasive Species Committee (OISC) is a voluntary partnership of private, governmental and non-profit organizations and individuals. Their mission is to prevent new invasive species infestations on the island of Oʻahu, to eradicate incipient species, and to stop established species from spreading. The group is concerned with all non-native invasive species threatening agriculture, watersheds, native ecosystems, tourism, industry, human health, or the quality of life on Oʻahu.

Mechanical Control

Mechanical control methods include manual pulling, digging, chopping or girdling. Mechanical control can be expensive because it is labor-intensive, although volunteers can be effectively utilized to conduct this type of project. Another potential drawback is the accompanying damage to the ecosystem in the process of weeding. Sometimes ground disturbance simply stimulates more growth of weedy species; eradicating an entire stand of one alien species can open the canopy to allow replacement by another opportunistic alien species. In some cases, this problem can be addressed by an alternative treatment method.[26] Regrowth can also be a problem if weeds are not completely killed or removed.

Chemical Control

Chemical control methods are also a necessary tool in invasive plant management, as mechanical control methods are not feasible in many native or semi-native communities. When used responsibly and with caution, herbicides can be an effective weapon. One particular advantage of herbicide use is that the soil is left undisturbed, and in many instances, the dead plant tissues form a ground cover that will impede the growth of alien plant seedlings. Non-restricted herbicides are carefully used by resource managers throughout the state in combination with mechanical and biological control.

Sometimes herbicides can negatively impact native species; therefore, generalist herbicides should be used sparingly in areas with a high occurrence of endangered species or sensitive and rare ecotypes. The method of herbicide application is also important. The use of CO^2 (carbon dioxide) cartridges for example, can minimize the risk to other plants. Since herbicides are not hazard or risk free, their use should be strictly monitored and in full compliance with state and federal regulations. Additional techniques for alien plant control, such as aerial spraying of herbicides, may be used in the future as these techniques are developed.

Biological Control

According to the Coordinating Group on Alien Pest Species (CGAPS),[27] biological control needs to be a key component of any effective long-term control program, as it has been considered the only cost-effective method for reducing the negative impacts of widespread, established priority invasive species. Biological control uses predators and disease organisms of invasive pests from their native ranges to damage targeted weeds. Finding these biological agents can be challenging; in their native habitat, many invasive weeds seem to be controlled by succession, rather than herbivores or parasites. The process of finding an agent can also incur high initial capital expenses, with uncertain results as well. The U.S. Army and State of Hawai‘i Department of Agriculture released two species of moth, *Mompha trithalama* and *Carposina bullata*, in an effort to control *Clidemia*, which is too widespread for effective chemical or manual control. Despite a large capital investment, no sign of moth

[26] For example, a girdle treatment without herbicide can be effectively used to kill *manuka*, particularly in areas with dense stands. This treatment kills the tree in place, and changes the light level of the subcanopy slowly, preventing colonization by weedy grasses such as *Axonopus fisifolius* (Burt, et al., 2000).

[27] CGAPS, the Coordinating Group on Alien Pest Species, is a multi-agency partnership organized by Federal, State, academic, and private cooperators working toward the effective protection of Hawaii's economy, environment, health, and way of life from harmful alien pests.

establishment was detected in the Army's monitoring (Burt, et al., 2000). The U.S. Forest Service is currently collaborating with entomologists in Brazil and Costa Rica to discover insects selectively feeding on *Miconia*, *Clidemia*, and strawberry guava. The agency expects to be able to develop release requests for some of these species within the next few years.

Additionally, the ecological requirements of the biological agent may be found only in part of the target species range. Therefore, a suitable biological control agent will probably only be effective in a segment of the insular range of the alien pest. Another potential problem is that as more species are introduced into the Ko'olau Mountains, the likelihood of unforeseen secondary impacts increases as it is impossible to screen the potential agent against all native species. The expense and the time necessary to verify that an agent is not only suitable, but unlikely to have negative side effects is a large limiting factor to the use of biological control.

For several species of weeds with large infestations, no effective control methods currently exist. In these cases, it is important for the KMWP to identify these problem species, take measures to prevent them from becoming established in the first place, and to support long-term research programs to improve control methods.

2. Feral Ungulates

Control of feral animals in key watersheds has been a priority in Oahu's forests since the establishment of the conservation districts in 1903. In more accessible regions, an aggressive public hunting program has provided some watershed protection, but in more remote areas where hunters seldom venture, feral pig damage is continuing. Specific management strategies for feral ungulate control will be based on both the severity of the threat, as well as topography and other natural features.

Management Goal:

The feral ungulate program has three simple approaches to protect the forested areas of the watershed from pig damage:

Approach #1: Eliminate pig populations in current and future fenced exclosures,

Approach #2: Stop ungulate damage and reduce levels of pig ingress in upland native forests,

Approach #3: Limit ungulate activity in lowland native and non-native forests to levels that allow maintenance of forest cover and species diversity.

These goals exhibit a few general trends that generally correspond to: 1) the level of ungulate activity, which is highest in lower elevation non-native forested areas, and 2) areas of high biological and hydrologic value, which are located at high elevation range. The table below summarizes the characteristics associated with each approach. For example, Approach #1 should be a **high** priority project applied in **high** elevation areas with **high** biological and hydrologic resources, **low** levels of ungulate activity, on a **small** geographic scale, with a relatively **short** time frame for accomplishing the goal. The application and success of the third approach would mark a highly significant advance in the feral ungulate management program, as the threat of feral pigs would be severely diminished.

Table 7. Summary of Approaches to Feral Ungulate Management Program

Approach	*Priority*	*Elevation Range*	*Value of Resources*	*Ungulate Activity*	*Geographic Scale*	*Time frame*
Approach #1	High	High	High	Low	Small	Short
Approach #2	Medium	Medium	Medium	Medium	Medium	Medium
Approach #3	Low	Low	Low	High	Large	Long

Recommended Actions	**Benefits**	**Yrs. 1-2**
Review existing survey data, consult with experts and landowners, study aerial photos as available, and conduct on-the-ground surveys as necessary to gain an understanding of pig population distribution and dynamics.	++++	✔
Employ staff, contractors or volunteers to utilize effective methods to control ungulate populations above or below fencelines or within fenced exclosures.	++++	✔
Seek partnerships with organized hunting groups such as Pig Hunters Association of O‘ahu and community volunteer hunters to utilize their skills for pig control.	++++	✔
Work with landowners adjacent to DoFAW hunting areas to improve hunter access and develop a pig management program.	++++	✔
Expand upon established fencing exclosures, in areas such as the Upper Helemano drainage of the ‘Ōpae‘ula fencing project, Upper Kawai Iki Drainage (leeward side) and Upper Kaluanui (windward side).	++++	✔
Build new fences in high priority areas (summit or riparian areas, along key ungulate ingress routes, along key ridges and valleys in the northern portions of the watershed area).	++++	✔
Maintain and enhance the 8 public hunting areas within the KMW area in conjunction with DoFAW.	++++	✔
Establish and regularly monitor transects in areas with heavy pig damage and where ungulate control programs have been conducted.	+++	✔
Support research for ungulate control.	++	

Fencing may be the most effective technique to control feral ungulates, but it is important to reiterate that in any given project area, a combination of the above strategies will be necessary to develop an effective ungulate control plan. A single method is seldom effective. Fencing is useful where desired forest reproduction, soil hydrologic values, existing vegetation, aesthetic values, and recreation are prevented or damaged by these animals. Fence projects can be developed as exclosures or strategic fencing. Exclosures, which entail fencing ungulates out of certain areas, will help to prevent water quality degradation of streams, protect threatened and endangered plants, reduce soil compaction and maintain soil productivity. Since a single pig could cause irreparable damage in these sensitive areas, the management goal here will be to eliminate all pig populations though a combination of management strategies.

It is also necessary to prevent the further ingress of ungulates upslope into more sensitive, pristine forests. Strategic fencing may be useful in these areas, but must be used in

combination with effective control methods above them and intensive hunting below. Fences should be constructed along ridgelines, and are most effective in combination with natural barriers such as cliffs, as costs can be reduced. Any proposed fences will not block existing public trails; crossings or gates can be installed in the fences wherever needed to ensure appropriate human access. Fences, in spite of their proven success, are maintenance-intensive and have some topographical constraints. In particular, the efficacy of strategic fences has been questioned in undulating terrain such as that in the summit area of the Koʻolau Range. Fence construction may also have potentially detrimental impacts by disturbing soil and vegetation, opening new areas to alien species invasions, or creating ungulate corridors.

Ungulate control measures are an essential affiliate component to fencing projects, and an essential tool to help reduce pig populations. Ungulate control methods such as hunting, trapping, baiting and snaring can be feasible options, given public support (USFWS, 1998). Hunting can best be utilized in areas that are easily accessible. In particular, volunteer hunting or contract hunting can be used in lower elevation areas not designated as state game management areas. KMWP may work with hunters to gain information on pig activity in exchange for controlled access to hunt. However, safety and liability concerns need to be addressed and a hunting protocol developed for private land areas. Trail, road, and access assessments would need to be conducted for these hunting areas. Hunting can be productive, providing that it is compatible with the activities of that particular area. There is an important distinction to be made however, between game management for public hunting, and reducing ungulate levels for management purposes. While both are important, they each have very different objectives. Hunting is not always a viable solution in remote areas, or even in important accessible ecologically sensitive areas.

In such areas – that are too remote, too steep, or too fragile for frequent hunting, as well as in areas with low pig density – snaring has been effectively employed as another ungulate control measure. It has also been used to reduce human exposure to injury in extremely rugged, wet terrain. Trapping with corral traps or box-traps and bait stations have been used to successfully remove pigs. The advantage of this kind of trapping is that it does not require the use of toxins. The disadvantages are that trapping is labor intensive, and its application is limited to areas within reasonable proximity to vehicular access. The FLIR (Forward-Looking Infrared) sighting technique is another control mechanism being proposed as an alternative to achieve eradication of ungulates in low-density areas or exclosures.

3. Other Non-Native Animals

Widespread control of small mammals is unrealistic, even along water corridors or sources. The management goal is therefore to minimize the impacts of small mammals on the watershed resources. The focal point of the non-native animal program is rats, which are ubiquitous throughout the watershed. Control projects should therefore target specific areas where non-native animals are threatening the resources and health of the forested ecosystem (i.e. – next to rare species, or special management areas) to direct management activities. Insect pests and disease also have the potential to cause severe destruction in the forested watersheds. Unfortunately, some insects that have significant effects on forest health, such as the black twig borer, do not have adequate controls at this time (Burt, et al., 2000). KMWP

supports ongoing research to develop methods to combat forest vectors and diseases that negatively impact forest health in the Ko‘olau Mountains.

Management Goal:
Reduce the impacts of rats and other small mammals, and promote control of other non-native animals as appropriate.

Recommended Actions	Benefits	Yrs. 1-2
Use appropriate rodent control methods, particularly in locations that are in proximity to native species. Ensure that control methods are consistent with goals of water quality protection.	+++	✔
Provide USFS and DOA access to conduct management for forest disease.	++	✔
Support the interagency Toxicant Working Group’s development of new control methods for non-native species such as rats, mice, mongoose, and invertebrate pests.	++	
Monitor the level of water-borne diseases from streams and water sources.	+	

Appropriate rodent control methods include traps, bait, toxicants, repellants and barriers. They are best used in locations that are in proximity to native species that rats have been known to prey on. Rat traps or poison-bait stations should be placed and maintained until rats are no longer a problem in selected areas. Black rats (*Rattus rattus*) and house mice (*Mus musculus*) respond well to diphacinone poison and to snap trapping. Mongooses also respond well to diphacinone baiting. Feral cats typically require larger traps than the ones used for mongoose.

4. Human Activities

There are an assortment of human activities occurring within the watershed area, including hiking, motorbike riding, native plant collection, illicit cultivation, illegal dumping, trespassing and vandalism. Concerns to date have been site-specific and on an isolated scale. Given the collected information, none of these activities have been identified as severe threats to the watershed resources. However, the sheer number and proximity of Oahu’s resident and tourist population makes the possibility of severe impacts from human activities a real one. The management program will focus on the enhancing positive human activities within the watershed, while minimizing site-specific threats, and monitoring human impacts across the landscape.

Management goal:
Enhance the capability for productive management actions within the watershed, and minimize the effect of unauthorized and destructive human activities.

Recommended Actions	Benefits	Yrs. 1-2
Build infrastructure (cabins/shelters) for management at the O‘ahu Forest NWR and Army land junction.	++++	✔

Recommended Actions	Benefits	Yrs. 1-2
Raise public awareness about watershed damage that can result from uncontrolled recreational activity, and develop strategies to control and manage human activities.	++++	✔
Create windward access to high resource management areas in the upper Koʻolau Mountains.	+++	✔
Establish human impact test sites to monitor human impacts on vegetation and soil disturbance.	+++	✔
Work with the DLNR and private landowners to identify and promote areas where public recreational or ecotourism activities can occur with minimal vulnerability to watershed vegetation and resources, effectively detouring human traffic from valuable, sensitive resource areas. Establish a policy statement concerning ecotourism development.	+++	
Conduct surveys or interviews to determine the watershed extent of human activities such as traditional native plant collection, motorcross activity, illegal cultivation, vandalism, waste disposal and trespassing.	+++	
Determine areas that have the greatest safety and liability hazards, and consider measures to address these hazards, such as developing public education signs and literature or monitoring access points to some sites or trafficways.	++	
Work with landowners and the DLNR to update the statewide trail database, which details conditions and other information regarding trails.	++	

Human activities can generally be managed through a combination of public education and the implementation of preventative measures. While education is the most effective preventive measure, signs may not be effective for trespass prevention and barriers may be necessary at key entry points for unauthorized bikers and hikers. Border patrol and fencing are generally not cost-effective options to prevent access. Monitoring of human activities and their impact on the natural resources of the watershed is also an important aspect of management. Research plots should be developed, with site selection based upon evidence of damage, traffic estimates and proximity to critical or sensitive resources.

Human impacts from traditional resource gathering might be abated by other programs aimed at increasing the feasibility of alternatives to plant collection. For example, programs to lower the work time required for community gardens or decrease the costs of commercial production can be cost-effective methods to reduce the likelihood that increasingly rare forest plant species will become endangered or be harvested to extinction. Nonetheless, it is important to ensure that plant collection practices are sustainable, and do not deplete rare native species, cause erosion, or compromise private property rights. Comprehensive research is lacking to determine where these resources are available and being collected, or how to ensure their sustainable use.

5. Aquatic Pollutants

Typical pollutants that come from forested areas include siltation, suspended solids, turbidity, nutrients, organic enrichment, toxins and pathogens. Since the majority of aquatic pollutants occurring in forested areas arise from erosion and runoff, prevention of soil disturbance is the best strategy for pollution abatement in the Koʻolau Mountains. Therefore, many of the

management strategies to address the aquatic pollutants are redundant to those in the invasive non-native plant and feral ungulate programs, as addressing these two threats reduces soil disturbance, increases vegetative health, and its corresponding ability to perform essential watershed functions. In fact, one of the primary BMPs prescribed for aquatic pollutants, called Conservation Land Management, directly coincides with the threats and human activities management sections of this management plan. The BMP prescribes land managers to carefully address trail use and management issues (including overuse and misuse), and to address invasive plant and animal species that contribute unnatural nutrient loads and increase vulnerability of steep areas to erosion.

However, until these sources of erosion (mainly ungulates) are brought under control throughout the entire KMW area, mitigating measures are needed to reduce the volume of surface runoff originating from disturbed areas. One of the important strategies will be to engage in erosion control in areas such as the Ala Wai watershed, where nutrient allocation TMDLs recommend a 52% and 55% reduction in nitrogen and phosphorus levels, correspondingly, in the forested areas of the watershed. These pollution abatement measures center around erosion control and revegetation, particularly of riparian areas, which are known to be effective in reducing sediment, nitrates, phosphates, and thermal pollutants. Other erosion site categories that warrant increased attention include trails, roads, bare and landslide areas, and damaged stream courses (USEPA and HDOH, 2001).

Management Goal:
Monitor the level of forested area pollutants and take mitigating measures to reduce these pollutants to acceptable levels.

Recommended Actions	**Benefits**	**Yrs. 1-2**
Stabilize exposed mineral soil areas to abate nonpoint source pollution.	++++	✔
Involve the EPA and DOH in KMWP to help address illegal dumping and contamination issues.	+++	✔
Implement programs to control and reduce littering and illegal dumping into the watershed and watercourses.	++	
Establish streamside vegetation monitoring sites to measure ungulate and alien plant damage.	++	
Promote Best Management Practices (BMPs) for land uses and activities that can introduce pollutants into water sources such as the Ala Wai Canal Watershed.	++	

Nonpoint source pollution abatement can be achieved by stabilizing exposed mineral soil areas through replanting with native plants or installing artificial vegetative riparian buffer zones along stream corridors or through vegetated filter strips. Vegetated filter strips improve water quality by removing nutrients, sediment, suspended solids, and pesticides, and are appropriate for use in areas adjacent to surface water systems that may receive runoff containing sediment, suspended solids, or nutrients.

Another streamside restoration management technique that may be useful is called blanketing, or mattressing.[28] Mattressing minimizes sediment loading and associated nutrient enrichment impacts downstream by acting as a buffer, disrupting the force of incoming flows, creating turbulence, lowering water velocities, causing deposition of sediment, and protecting banks. These are best used as part of a system that includes a component to deter undercutting at the bank interface, such as riprap or gabions.

6. Wildfire

The primary management goal of the wildfire management program is to prevent wildfire occurrence and to minimize the effects of a wildfire by aggressively suppressing it. Prevention will be focused on identifying areas of high fire risk, eliminating or abating the hazards contributing to this risk (i.e. – excessive human traffic or alien grasslands), and supporting fire prevention education. Once a wildfire has occurred, fire suppression is initiated with assistance from other fire services, including DoFAW and the Honolulu Fire Department. While the first and foremost concern in wildfire control is to prevent harm or damage to people and property, minimizing environmental impact is also a priority, with an extensive list of BMPs for firefighting techniques like prescribed burns and firelines.

Management Goal:
Take measures to reduce wildfire occurrence and minimize wildfire impacts.

Recommended Strategies	**Benefits**	**Yrs. 1-2**
Create a fire risk map, which combines the factors related to fire probability. Identify high fire risk areas that coincide with areas of high resource value and target these for fire prevention.	++++	✔
Establish an interagency fire council consisting of all fire services.	++++	✔
Identify and establish helicopter-landing zones, as necessary.	++++	✔
Educate the public about wildfire dangers, with emphasis on the ecological consequences of fire. Conduct such education in areas of high traffic near high fire risk areas.	+++	✔
Cooperate with DoFAW and other fire fighting agencies in post-fire restoration considerations such as erosion control, revegetation and streamside management.	++++	
Reduce "flash" fuels in high use areas.	+++	
Provide firefighters with information about natural resources, natural resource management techniques and watershed access points to minimize harm to areas of high resource value.	++	
Post public notices/news releases declaring high fire danger periods, and fire prevention/high fire danger warning signs and posters.	++	

[28] Blanketing or mattressing is a form of soil bioengineering, which uses a blanket woven of live green cuttings and biodegradable fiber, geotextile, or wire, and is laid into a slightly excavated depression in the bank, anchored with live or wooden stakes, and often punched through with live stakings. It is then covered with soil and watered repeatedly to fill voids and to facilitate sprouting.

B. Water Resources and Watershed Management

Eliminating threats naturally increases the water quality and health of stream ecosystems. Therefore, many of the management strategies needed to preserve the health and integrity of the watershed and its resources have been previously delineated in the aquatic pollutants and invasive plant and animal species sections. The focus of the Water Resources and Watershed Management program is to bridge the connection between these management activities and monitor their impact on the quality and integrity of ground water, surface waters, and aquatic resources.

Ground water protection presents challenges that differ from those encountered with surface waters. Aquifer boundaries, for example, often do not coincide with watershed boundaries. With the movement and circulation of groundwater beneath O‘ahu, aquifer boundaries may span several watersheds. A comprehensive monitoring protocol must be designed to address specific questions about ground water in addition to surface water.

Although there are many factors that contribute to the overall health of surface waters, one of the basic factors is adequate stream flow. Surface water data are vital to determine the flow requirements necessary to support instream uses, such as fisheries, wildlife, aesthetic, and recreational uses. The primary mechanism that has been used in Hawai‘i to monitor aquatic health has been the Hawaiian Stream Bioassessment Protocol (HSBP), which is based on both physical habitat properties of the stream as well as biological criteria. Although the criteria are focused primarily on the provision of habitat and the condition of native macrofaunal communities, which are taken as indicators of stream health, some of the indices are useful for strict purposes of water quality as well. However, the protocol was initially designed for use in lower streams and would have to be modified if applied in the upper watershed areas of the Ko‘olau Mountains. The HSBP is most typically used to establish a baseline for the biological integrity of a stream against which degradation or improvement can be measured.

Management Goal:

Monitor and improve the quality and integrity of ground water, surface waters, and aquatic environments.

Recommended Actions	Benefits	Yrs. 1-2
Cooperate with other watershed partnerships to develop programs to monitor long-term impacts to water quality and watershed health.	++++	✔
Collaborate with USGS, DOH, EPA and CWRM to develop a monitoring program to measure sedimentation, stream flow, turbidity and nutrients on a subwatershed, valley or *ahupua‘a* level.	+++	✔
Work with agencies and experts to modify the Hawai‘i Stream Bioassessment Protocol to be operable in *mauka* stream areas.	++	
Work with agencies and experts to modify the Hawai‘i Stream Bioassessment Protocol to be operable in *mauka* stream areas, and assess the biological integrity of streams in the upper Ko‘olau Mountains as necessary.	++	
Monitor ground water areas with >60-inch isohyet rainfall boundaries, locations of streams and wells and location of important aquifer systems for salinity levels.	+	

Although monitoring is often perceived as an expensive venture, there are many alternatives that can reduce monitoring program costs. Stream, sediment and water monitoring gages can be purchased in a 50% cost-sharing agreement with USGS if done in partnership with the State. There are also numerous existing gages that area already funded throughout the Koʻolau Mountains, data for which is available to the KMWP. Additionally, costs have been dramatically reduced in various monitoring projects by the contributions of volunteers, school, community or other groups' assistance in monitoring activities. Some of these organizations are listed in Appendix E. Training and outreach for these groups could be provided by USGS.

C. Biodiversity Protection

Biodiversity is often used as an indicator of ecosystem health or stability, as the structure and composition of the plant communities, the status of rare native species populations, and the level of species diversity are all indicators of forest health. Although the primary focus of the KMWP is watershed protection, a diverse forest is a more resilient and healthy forest, and endangered and threatened species are of concern to the KMWP to the extent that they contribute to the diversity of our ecological systems. Rare species management and monitoring is also important to ensure that prospective watershed management projects do not compromise the health and survival of these treasured species. Economic analysis suggests that KMWP should take steps to protect these species now, before they become depleted. The cost of restoring Oahu's endangered species to viable populations has been calculated to be approximately $44 million (Gutrich and Donovan, 2001).

The presence of endangered and rare species should be a consideration when locating fences or deciding on the viability of a management project. However, the specific management of endangered populations and species, while important and supported by the KMWP, does not have as great an impact on the water resources of the Koʻolau Mountains. Management strategies will focus on the identification and protection of rare species within the KMW area and assistance of agencies or organizations specifically engaged in rare species management. The partnership can also increase diversity through rehabilitation of degraded habitats, with priority on those areas of importance to critical water resources. Biodiversity management will often occur in conjunction with threat control, as reforestation or plantings may be needed in areas with widespread degradation or denudation.

Management Goal:
Identify and protect rare species within the KMW and ensure that forest structure and composition, species diversity, ecosystem health and resilience are maintained so the ecosystem functions of the forest are preserved.

Recommended Actions	Benefits	Yrs. 1-2
Conduct biological surveys to identify rare element locations (plants, animals and ecosystems) where landowners are willing. Update maps with survey information. Priority Locations: Oʻahu Forest NWR, Kaluanui to Kaipapaʻu, Central Oʻahu section of ʻEwa Forest Reserve.	++++	✔

Recommended Actions	Benefits	Yrs. 1-2
Take measures, such as fencing exclosures or trail rerouting, to protect rare biological elements, particularly if projects may impact their survival.	++++	✔
Replant weeded priority areas with native plants, as appropriate. Use private nurseries or BWS's Hālawa facility to provide plants for reforestation/restoration.	+++	✔
Monitor the reproduction and recovery of native vegetation after threat control projects, such as fencing and weed removal.	+++	
Cooperate with various agencies and organizations that manage rare plant populations to conduct surveys or update rare species population data.	++	
Monitor rare or indicator species as an indicator of forest health.	++	

D. Cultural Resources Management

Although the focus of the KMWP partnership is on the protection of the water and natural resources, land and nature are integral to the tapestry of Hawaiian culture. The management plan is not designed for the specific conservation of these resources, but watershed management is a holistic endeavor and must take into consideration the protection of cultural resources, particularly if they are threatened by proposed management activities. The presence of cultural resources should be a consideration when locating fences or deciding on the viability of a management project. In addition to historic and archaeological sites, KMWP also recognizes current-day traditional Hawaiian gathering practices and generally supports such activities, providing they are not in conflict with the goals of the KMWP and are sustainably conducted.

Management Goal:
Ensure that cultural practices, archaeological and other cultural sites within the KMW area are identified, protected and enhanced.

Recommended Actions	Benefits	Yrs. 1-2
Consult with appropriate agencies and ensure that significant cultural and historic resources that are identified are appropriately protected and not jeopardized.	++++	✔
Link with traditional resource gatherers to assist them in developing a strategy to increase the availability of resources available to them and to sustainably manage those resources.	++++	✔
Collaborate with cultural resource specialists to survey, document and protect culturally significant areas where management projects may take place.	+++	✔
Develop a policy statement on how KMWP will respond to access for traditional and cultural practices.	+++	✔

Not all areas of the KMW have been surveyed for cultural and historic resources. A comprehensive survey of the watershed area would be useful, as the priority for KMWP is to ensure that management projects do not infringe upon existing cultural resources. However, since such an endeavor would be extremely time-consuming and expensive, it may be more practical to conduct surveys on a project-by-project basis. Surveys should utilize a variety of

methods, such as on-site visits and interviews with Hawaiian elders and others with knowledge of cultural practices in these areas. KMWP should also consult with the SHPD, the Office of Hawaiian Affairs (OHA), Kamehameha Schools and other organizations and agencies to obtain the proper clearance and documentation prior to conducting activities that could negatively affect cultural resources in the Ko‘olau Mountains.

E. Education, Awareness and Public Outreach

Educating the public about the watershed, its value, threats, and management activities assume primacy in a large, publicly accessible, high-profile watershed like the Ko‘olau Mountains. Education ties into the “Human Activities” program of this management plan, as conservation education and watershed awareness are critical to reducing unwanted human impacts on the landscape. Beyond education, it is also advantageous to develop more intimate contact with the public through community outreach. Volunteer groups have proven successful in many watershed management activities, especially labor-intensive efforts such as fence construction, weed control, outplanting and trail maintenance in accessible areas. Community partnerships can also be a valuable tool in some instances. It is through a combination of these activities (i.e. – a program that disburses informative material, conducts community outreach, utilizes concerned volunteer groups and individuals, and establishes working partnerships) that the KMWP will engender a public constituency that is supportive of its watershed management activities.

Management Goal:
Build public understanding and support for the management of the watershed.

1. Media and Public Education

Media and public education programs are by nature often focused on one-way communication – the dissemination of information through community newsletters, newspaper and magazine articles, the Internet, television and radio coverage, brochures and other special publications for target audiences.

Recommended Actions	Benefits	Yrs. 1-2
Work with media representatives to bring conservation activities and successes at KMWP to public attention.	++++	✔
Create a brochure for the KMWP and public service announcements that describe KMWP and its watershed protection efforts, and promote watershed awareness.	+++	✔
Update or revise the KMWP web page to reflect progress.	+++	✔
Develop materials (i.e. – booklet, CD-ROM, video) on the natural and cultural history of Ko‘olau Mountains Watershed to disseminate to local schools, community groups, and businesses.	++	
Develop public education materials directed at watershed users such as native gatherers, hunters and hikers.	++	
Develop a policy statement for sensitive threat control methods and other water quality concerns.	+	

2. Community Outreach and Education

A media-based campaign is complemented by two-way communication, in the form of community outreach and education. Direct interaction with community members and the public is an effective mechanism to promote support of conservation activities in the KMW area. Successful education efforts have often targeted schools and younger students, with the belief that informing younger generations not only plants the future seeds of effective conservation, but also has the mushrooming effect of parents being educated by their children. Outreach activities can take various forms, including field trips, workshops, public clean-up events, service trips, lectures or slide shows.

Recommended Actions	Benefits	Yrs. 1-2
Conduct a variety of community outreach activities, focusing on communities and areas that are impacted by project activities.	++++	✔
Using the Koʻolau Mountains as a natural laboratory and case study, utilize existing environmental education programs, and assist them in integrating watershed concepts and protection advocacy into curriculum.	+++	
Promote outreach activities and increase access to Hawaiian cultural sites in education to showcase the integration between nature and culture.	++	

3. Volunteer Opportunities

Volunteerism is a mutually beneficial practice: not only does it reduce project costs for KMWP, but it also increases community interest in watershed conservation and builds local stewardship values. Local volunteers are an especially invaluable resource for watershed monitoring, as they have both interest in and proximity to watershed resources. Volunteer projects on which KMWP should focus are those that:

- Address a high natural resources management priority;
- Focus on restoration and protection;
- Are hands-on in nature, bringing people into direct contact with the watershed;
- Match volunteer skills and interests with appropriate projects;
- Emphasize small volunteer groups with stewardship; and
- Allow volunteers to see visible results within the period of their commitment.

Mālama Hawaiʻi (www.malamahawaii.org) formed in 1999 as a network of partners and stakeholders to ensure that "Hawaiʻi is a place where the land and sea are cared for and communities are healthy and safe for all people." As of November 2001, more than 75 Hawaiʻi organizations were working together as a cooperative group to foster social interaction and promote coordination between groups. One of the initiatives of Mālama Hawaiʻi is the Volunteer Stewardship Network (VSN), which links volunteers from community groups, non-profits, schools, government and non-government organizations across the state to preserve, protect and restore Hawaii's natural environment. The VSN matches potential volunteers with meaningful opportunities that are most appropriate to their interests, skill levels, time commitment, and geographic location.

Recommended Actions	Benefits	Yrs. 1-2
Create volunteer projects for existing volunteer networks to assist with watershed resource management projects, such as labor-intensive efforts like weed control, riparian restoration and trail maintenance in accessible areas.	++++	✔
Link with the VSN to coordinate/post volunteer work trips, recruit and train volunteers, and understand liability issues.	++++	✔
Provide training to local community groups, watershed partnerships or school groups in activities such as water quality, stream or vegetation monitoring techniques through interagency collaboration, where feasible.	++++	✔
Include volunteers as partners when planning and implementing monitoring efforts.	+++	✔

4. Community Partnerships

Inclusion in the KMWP is currently limited to large landholders within Koʻolau Mountains Watershed management boundaries. However, the watershed supports a large population, and there are a number of local groups interested in watershed protection. Some of these are profiled in Appendix C. While the general public may not be involved in day-to-day decision making on KMWP lands, their perspectives and views should still be understood and considered in order to build a broader public consensus for the KMWP (Daniels and Walker, 1996). These local watershed groups have mainly concentrated their efforts on the populated, *makai* areas, maintaining a different focus from the KMWP. In the long run however, the KMWP recognizes the importance of the *ahupuaʻa* concept in watershed management, understanding that effective watershed management will entail upland areas and *ahupuaʻa*-based groups to discuss sustainable use and integrated management for the entire watershed area. However, as the size of a partnership and the number of purposes it serves increases, so increases the complexity of equitably distributing costs and benefits within the watershed (NRC, 1999).

Recommended Actions	Benefits	Yrs. 1-2
Develop relationships with surrounding land managers, businesses, communities, traditional watershed resource users and other stakeholders to leverage resources and create a network of KMWP supporters.	++++	✔
Maintain a database of watershed partnership community groups and keep them informed on KMWP projects.	++++	✔
Promote partnerships with university and college professors to conduct management-related research activities within the Koʻolau Range.	+++	✔
Establish contact and work with organizations focused on traditional watershed users such as native gatherers and public hunters.	+++	
Promote joint educational opportunities with other watershed partnerships.	+++	

F. Administrative Coordination and Communication

Implementation of the management plan is a long-term commitment that requires effective management of not only the natural resources, but also perhaps even more importantly, the administrative coordination of KMWP. The recommended strategies in this section of the

plan are directed to assist KMWP in maintaining its administrative functions. This includes hiring of personnel and developing and maintaining physical infrastructure. The KMWP MOU asserts that the partners will work together to formulate watershed projects and join in cooperative efforts to seek funds for these projects. Cooperation between partners is a critical trait of a healthy partnership and explicit attention should be given to foster success toward this internal goal. KMWP should also maintain relationships with adjacent landowners in the KMW area, keeping them informed of activities by inviting them to sit in on meetings or view successful joint project areas.

Management Goal:
Ensure that appropriate infrastructure exists to allow for effective watershed management.

Recommended Actions	**Benefits**	**Yrs. 1-2**
Hire a watershed partnership coordinator to: 1) supervise the implementation of the plan, 2) raise and manage needed funding from a variety of sources, 3) assist partners in implementing projects, and 4) hire staff. Obtain needed equipment, transportation, and communication systems.	++++	✔
Complete the process for an Environmental Assessment for priority KMWP projects.	++++	✔
Strive for a 100% participation rate from large landowners within the KMW area. Continue active recruitment of other partners within the KMW area.	++++	✔
Conduct a site conservation planning process with partners to determine priority management sites for future years.	++++	✔
Establish a central data bank as a repository for information on the KMW area.	++++	✔
Maintain communication amongst partners through seminars, workshops or other events to facilitate information sharing. Develop clear and effective processes for intra-partnership communication.	+++	✔
Involve other affiliate partners in the KMWP, including lessees and land managers, state and federal government branches and divisions, and other organizations working in the watershed.	++	
Compile a list of public statutes, rules, laws, regulations and codes that may affect KMWP and management activities.	+	

VI. Monitoring and Indicators

This chapter outlines a general structure for watershed monitoring and provides prospective indicators to gauge the success of the management programs described in Chapter V. A requisite part of this monitoring process will be the establishment of baseline measures, as the protection and enhancement of the KMW Area must be measured against these initial conditions.

The development of a monitoring program brings KMWP back to its foundation and genesis by directing the focus of its efforts and energies on vital resources. Monitoring should be directly linked to KMWP goals and objectives. With the Memorandum of Understanding (MOU) as its guiding document (See **Appendix F**), the chief goal of the KMWP is to "sustain the future quality and quantity of Oahu's water supply." The MOU describes the primary mechanism to achieve this goal as the maintenance of a healthy forested watershed. Secondly, the MOU also states that the KMWP will develop projects to address threats to the watershed. The MOU asserts that partners will work together to formulate watershed projects and join in cooperative efforts to seek funds for these projects.

Three monitoring programs and suggested indicators are suggested to address these partnership objectives. These programs seek to:

A. Monitor the relationship between healthy forests and healthy water;
B. Investigate the efficacy of threat abatement projects and their impact on the health of the forest and water resources; and
C. Tend to the management success of the KMWP, as good coordination is just as critical as project development to a successful partnership.

It is imperative that KMWP develop protocols to conduct these three monitoring programs. Each of the goals will likely have different timelines, as the results of some programs may not be visible for years. In those cases, it is important to establish short-term indicators as well, so that progress can be shown throughout the entire lifespan of the project. The monitoring protocol that KMWP adopts will also need to describe other details such as the frequency of monitoring, methodology for data collection, principal investigators, responsibility and a timeline for results.

A. Relationship between Forest Health and Water Quality and Quantity

Initially, it is essential to establish a baseline survey of the resources within the watershed. This requires clear measures of both forest health and water quality and quantity in order to gain an understanding of the nature and extent of water resources and how forests impact them. Long-term data collection provides valuable information about the behavior and response of water resources to various stresses, such as ground water withdrawals, droughts, and deforestation or changes in forest vegetation (DLNR, 2001a).

Some monitoring projects are already in place within the Koʻolau Mountains and may be of utility to the KMWP. The School of Earth and Ocean Science and Technology (SOEST) at

the University of Hawai‘i supports a National Oceanic and Atmospheric Administration (NOAA)-sponsored CISNet (Coastal Intensive Site Network) project in Kāne‘ohe Bay. Initiated in 1998, this long-term project aims to monitor water quality and sediment processes in Kāne‘ohe Bay and examine linkages between watershed events and responses of the Kāne‘ohe estuarine/coral reef ecosystem. Of particular interest is the question of how regions of the Bay that receive flow from segments of the watershed with different land-use patterns respond to stream and groundwater discharge.

The aquatic and forest health indicators can be correlated in a subwatershed area where monitoring of these indicators can be consistently, and easily collected. Information on surface water quality has been collected in Hawai‘i since the 1960s. Monitoring of stream water is best done at instream stations, a full listing of which can be found in the USGS Hawai‘i Water-Data Report HI-00-1. Once an appropriate site is selected, it can be used as a research plot to manipulate the health of the forest and gauge such impacts on the water quality of the area. Management projects can also be tested in this area as a form of adaptive management, where the impacts of different projects are measured, and the management program subsequently modified depending on the results of the first “management trial”. The primary indicators for this management program are listed below:

Water Quality and Quantity Indicators:

- Area and percent of forest land with significant soil erosion
- Levels of nutrients, dissolved oxygen, suspended sediment, turbidity, siltation or temperature change
- Basal stream flow of perennial streams

Forest Health Indicators:

- Incidence of disease or pest infestation
- Percent forest cover by forest type
- Population and range of forest indicator species

B. Management Program Indicators

The following is a list of indicators that may be used to gauge the success of the various management programs. Project monitoring should take place in conjunction with baseline water quality and forest health monitoring in order to correlate the impacts of each management project to the ultimate goals of the KMWP – the sustenance of water quality and quantity via the health of the watershed. The best types of indicators are direct measurements that show the impact of the program on the resources of the watershed. The results are visible and easily measurable. For example, changes in the percentage of native forest cover can be measured after an invasive species removal and forest restoration project.

Surrogate measures may be more feasible and desirable in some cases. Surrogate measures monitor the efforts of the project as opposed to the impacts or results. For example, the number of brochures distributed or airplay minutes of public service announcements would be good surrogate measures for the level of public awareness, which would otherwise be a challenge to quantify and would probably require interviews. Surrogate indicators may be more appropriate for projects where:

- the results of the project may not be as tangible or difficult to quantify or measure
- the relationship between management actions and impacts may not be directly attributable, or
- results only appear after a long investment period.

Both direct and surrogate indicators are included as potential indicators for each management program.

Threat Management

Invasive Non-Native Plant Species Program

- Percentage cover of invasive weeds vs. native forest cover
- Temporal change of invasive species distribution
- Number of weed control projects completed

Feral Ungulate Program

- Ungulate sign in plots or along transects (scat, soil disturbance, browse evidence)
- Miles of fencing, or number of fencing projects
- Hunting catch per effort (pigs caught/hour of investment)
- Percentage of watershed area accessible to controlled hunting programs

Other Non-Native Animal Program

- Rate of rodent trapping success
- Level of forest disease incidence

Human Activities Program

- Condition of selected high traffic trails and access routes (maintenance levels)
- Impact of humans on soil compaction, vegetation disturbance, or new trail cutting
- Number of hikers or people involved in outdoor recreation

Aquatic Pollutants Program

- Erosion area and runoff rates
- Percent of riparian areas along streams
- Number of reforestation/rehabilitation projects

Wildfire Program

- Number and extent of fires in the area
- Acres of flash fuels removed

Water Resources and Watershed Management:

- Rate of stream flow, amount of sedimentation and water temperature
- Level of deep monitor wells, ground-water recharge rates and aquifer sustainable yields
- Level of rainfall gauging and fog drip
- Presence of biological indicator stream fauna

Biodiversity Protection:

- Viable populations of endangered/threatened species
- Number of restoration projects/outplantings
- Acres of native forest cover

Cultural Resources Management:

- Number of surveys/consultations conducted for cultural sites
- Number of cultural sites or traditions identified and protected

Education, Awareness and Public Outreach Program

- Number of brochures available/distributed
- Number of volunteers or volunteer hours used in management activities
- Number of website hits or updates
- Hours spent in direct contact with communities

C. Administrative Coordination and Communication Indicators

This monitoring program is designed to insure that coordination and communication are effective, that the partners are participating, and that progress is being made to sustain and develop KMWP as an organization. These simple monitoring indicators may include:

- Number of cooperative on-the-ground projects, and number of partners involved
- Number of policy changes or policy statements developed
- Dollars expended for watershed protection projects
- Funding dollars acquired
- Partner attendance to meetings
- Number of seminars, workshops or other events to facilitate information-sharing
- Partnership membership rate

VII. 2002-2003 Action Plan and Estimated Costs

This section presents a four-point action plan to guide and expedite KMWP's progress through its first two years. The action plan is part process, describing a stepwise recipe for management success. It is also part substance, outlining specific tasks (culled from the management strategies in Chapter V) to implement the action plan. The action plan is not sequential; some tasks, such as community outreach, monitoring infrastructure and project approvals must necessarily be performed prior to, or concurrent with other tasks. Cost estimates are provided for these tasks to help the action plan serve as a practical tool.

A. Implement immediate watershed management projects to show positive results.	
Tasks	*Estimated Costs*
1. Hire and equip a coordinator.	
• Hire a watershed partnership coordinator to: 1) supervise the implementation of the plan, 2) raise and manage needed funding from a variety of sources, 3) assist partners in implementing projects, and 4) hire staff.	$75-100,000/year
• Obtain needed equipment, transportation, and communication systems.	
2. Get permits and approvals for high-priority projects.	
• Complete an Environmental Assessment for priority projects.	N/A (by Coordinator)
• Consult with appropriate agencies and ensure that significant cultural and historic resources that are identified are appropriately protected and not jeopardized.	N/A
3. Implement high-priority projects.	
• Expand upon established fencing exclosures, such as the Upper Helemano drainage of the ʻŌpaeʻula fencing project, the Upper Kawai Iki Drainage and Upper Kaluanui Drainage.	$200,000 for all three projects
• Build infrastructure (cabins/shelters) for management at the Oʻahu Forest National Wildlife Refuge and Army land junction.	$8-10,000/shelter
• Employ staff, contractors or volunteers to: 1) utilize effective methods to control ungulate populations above or below fencelines or within fenced exclosures, and 2) control priority weeds.	$150,000/year
• Maintain and enhance the eight public hunting areas within the KMW area in conjunction with DoFAW.	N/A
• Initiate a control strategy for priority weed species in the watershed using a variety of management techniques, and support the Oʻahu Invasive Species Committee on projects that target KMW Area invasive weeds.	N/A

B. Plan and implement the second round of projects.	
Tasks	*Estimated Costs*
1. Gather existing information on threats and resources.	
• Review existing survey data, consult with experts and landowners, and study aerial photos as available to gain an understanding of pig population distribution and dynamics.	$3,000
• Collaborate with cultural resource specialists to document and survey culturally significant areas where management projects may take place.	$10,000/year
2. Survey areas where information on threats and resources are lacking.	
• Conduct on-the-ground surveys as necessary to gain an understanding of pig population distribution and dynamics.	$20,000
• Conduct biological surveys to identify rare elements and priority weed locations where landowners are willing. Update maps with survey information. Priority Locations: O‘ahu Forest National Wildlife Refuge, Kaluanui to Kaipapa‘u, Central O‘ahu section of ‘Ewa Forest Reserve.	$50,000
3. Work with landowners and other partners to plan and get approvals for the second round of projects.	
• Conduct a site conservation planning process with partners to determine priority management sites for future years.	N/A (by Coordinator and partner staff)
• Consult appropriate agencies and organizations to obtain proper clearance and documentation for second round of projects.	N/A
4. Implement second round of projects (examples below).	
• Build new fences in high priority areas (summit or riparian areas, along key ungulate ingress routes, along key ridges and valleys in the northern portions of the watershed area).	Approx. $75,000-100,000 / mile
• Stabilize exposed mineral soil areas to abate nonpoint source pollution. Replant with native plants in weeded areas. Use private nurseries or the Board of Water Supply Hālawa facility to provide plants for reforestation or restoration.	$5-10,000/acre for removal and reforestation
• Use appropriate rodent control methods, particularly in locations that are in proximity to native species. Ensure that control methods are consistent with goals of water quality protection.	$10,000
• Create windward access to high resource management areas in the upper Ko‘olau Mountains.	Up to $2,500/mile

B. Plan and implement the second round of projects.	
5. Develop management strategies and policies.	
• Create a fire risk map, which combines the factors related to fire probability. Identify high fire risk areas that coincide with areas of high resource value and target these for fire prevention. Identify and establish helicopter-landing zones, as necessary.	$6-12,000
• Provide US Forest Service and State Department of Agriculture access to conduct management for forest disease.	N/A
• Involve the US Environmental Protection Agency (EPA) and State Dept. of Health (DOH) to help address illegal dumping and contamination issues.	N/A
• Develop a strategic plan to control and manage human activities.	N/A
• Develop a policy statement on how KMWP will respond to access for traditional and cultural practices.	N/A

C. Build the KMWP's capacity to measure results.	
Tasks	*Estimated Costs*
1. Establish monitoring programs.	
• Collaborate with US Geological Survey, EPA, DOH and the Commission on Water Resource Management to develop a water monitoring program to measure sedimentation, stream flow, turbidity and nutrients on a subwatershed, valley or *ahupua'a* level.	~$10,000/stream gage; ~$20,000/year to maintain sediment gage; costs vary w/ conditions
• Establish human impact monitoring test sites for measuring vegetation and soil disturbance.	$20,000/year
• Establish and regularly monitor transects in areas with heavy pig damage and where ungulate control programs have been conducted.	$20,000/year
• Develop and implement a weed control efficacy monitoring program, including both follow-up monitoring with clear methods to determine the effectiveness of control efforts.	$15,000/year
• Cooperate with other watershed partnerships to develop programs to monitor long-term impacts to water quality and forest health.	N/A
2. Develop a comprehensive database.	
• Establish a central data bank as a repository for information on the Ko'olau Mountains watershed area.	N/A

D. Build partnership strength and capacity.	
Tasks	*Estimated Costs*
1. Recruit additional partners to KMWP.	
• Strive for a 100% participation rate from large landowners within the KMW area. Continue active recruitment of other partners within the KMW area.	N/A
• Maintain communication amongst partners through seminars, workshops or other events to facilitate information sharing. Develop clear and effective processes for intra-partnership communication.	N/A
2. Develop relationships with immediate stakeholders and key partners to augment cooperation and support for KMWP and its projects.	
• Develop relationships with surrounding land managers, businesses, communities, traditional watershed resource users and other stakeholders to leverage resources and create a network of KMWP supporters.	N/A
• Work with landowners adjacent to DoFAW hunting areas to improve hunter access and develop a pig management program.	N/A
• Seek partnerships with organized hunting groups such as Pig Hunters Association of O‘ahu and community volunteer hunters to utilize their skills for pig control.	N/A
• Work with botanical gardens, the green industry and DOA to address the spread of invasive species.	N/A
• Establish an interagency fire council consisting of all fire services.	N/A
• Link with traditional resource gatherers to assist them in developing a strategy to increase the availability of resources available to them and to sustainably manage those resources.	N/A
• Promote partnerships with university and college professors to conduct management related research activities within the Ko‘olau Range.	N/A
3. Conduct public outreach and education to develop the support base for KMWP and watershed management.	
• Raise public awareness about watershed damage that can result from uncontrolled recreational activity.	$10,000/year
• Educate the public about wildfire dangers, with emphasis on the ecological consequences of fire. Conduct such education in areas of high traffic near high fire risk areas.	$10,000/year
• Create a brochure for KMWP and public service announcements that describe KMWP and its watershed protection efforts, and promote watershed awareness.	$20-50,000

D. Build partnership strength and capacity.	
• Conduct a variety of community outreach activities, focusing on communities and areas that are impacted by project activities.	$10,000/year
• Work with media representatives to bring conservation activities and successes at KMWP to public attention.	$10,000/year
• Update and revise the KMWP web page to reflect progress.	N/A
• Maintain a database of watershed partnership community groups and keep them informed on KMWP projects.	N/A
4. Establish and sustain a volunteer workforce.	
• Create volunteer projects for existing volunteer networks to assist with watershed resource management projects, such as labor-intensive efforts like weed control, riparian restoration and trail maintenance in accessible areas.	$5,000/year
• Link with the Volunteer Stewardship Network to coordinate/post volunteer work trips, recruit and train volunteers, and understand liability issues.	N/A
• Include volunteers as partners when planning and implementing monitoring efforts.	N/A
• Provide training to local community groups, watershed partnerships or school groups in activities such as water quality, stream or vegetation monitoring techniques through interagency collaboration, where feasible.	N/A

VIII. Summary of Management Plan

Hahai no ka ua i ka ululā'au – "Rains always follow the forest"

This unofficial motto of the Ko'olau Mountains Watershed Partnership is an eloquent reminder of the value of the Ko'olau watershed's forested areas. This complex ecosystem produces a multitude of benefits, not only for the island of O'ahu, but for the entire State of Hawai'i. Everyone relies on water and other natural resources to exist. Healthy watersheds are vital for a healthy environment and economy. This management plan outlines these varied resources within the watershed. The natural resources - soils, water, air, plants, and animals are the most conspicuous resources within the watershed. Many areas of the upper Ko'olau Mountains are still wild places, but people are inexorably tied to the landscape and have left indelible marks on the land, in the form of land use, management, recreation, facilities and culture. Humans are just as much a part of the ecosystem as the plants and animals, and to ignore the sociocultural resources of the watershed for the biophysical, or vice versa, is to underestimate the value and benefits of the Ko'olau Mountains Watershed.

These valuable resources are currently threatened by a variety of natural and anthropogenic sources. Invasive non-native plant species strangle and crowd out native species; feral pigs destroy native understory plants, causing erosion and degrading water quality; and rats and other non-native animals prey on native species. Humans also have the capacity to negatively affect the watershed in many ways. At times, wildfires and aquatic pollutants naturally occur in the ecosystem; at other times, humans exacerbate their effects and increase their frequency.

Landowners within KMWP boundary have each been faced with these challenges in order to manage the resources with which O'ahu has been blessed. With the formation of the Ko'olau Mountains Watershed Partnership, a synergy has been created, where the efforts of one now become of the efforts of many, and the resources, knowledge and time to battle these threats to the watershed can be shared amongst the partners. Management can truly begin at the scale of the watershed, breaching property boundaries and directly tackling problems where they exist on the land.

This management plan proposes a slate of management activities that will address these threats to the watershed. It also includes activities to promote water resources and watershed management, biodiversity protection, cultural resource management and education, awareness and public outreach. Ultimately, it is still to be seen whether these management activities will affect the quality and quantity of the resources within the Ko'olau Mountains, but the management plan seeks to ensure that this does happen, outlining indicators to assess whether projects and programs are effectively meeting the goals for which they were intended. The plan functions as a template to guide the process of watershed management. It is far from complete; but then again, it never will be. As the threats, priorities and issues surrounding watershed management meander and change like a mountain stream, so will this management plan. As a "living document," it will grow, adapt and find its place, just as the forests within the Ko'olau Mountains Watershed have evolved into a complex ecosystem with a healthy balance between all of its elements − the water, plants, animals, and people.

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Appendices

A. Maps and Overlays

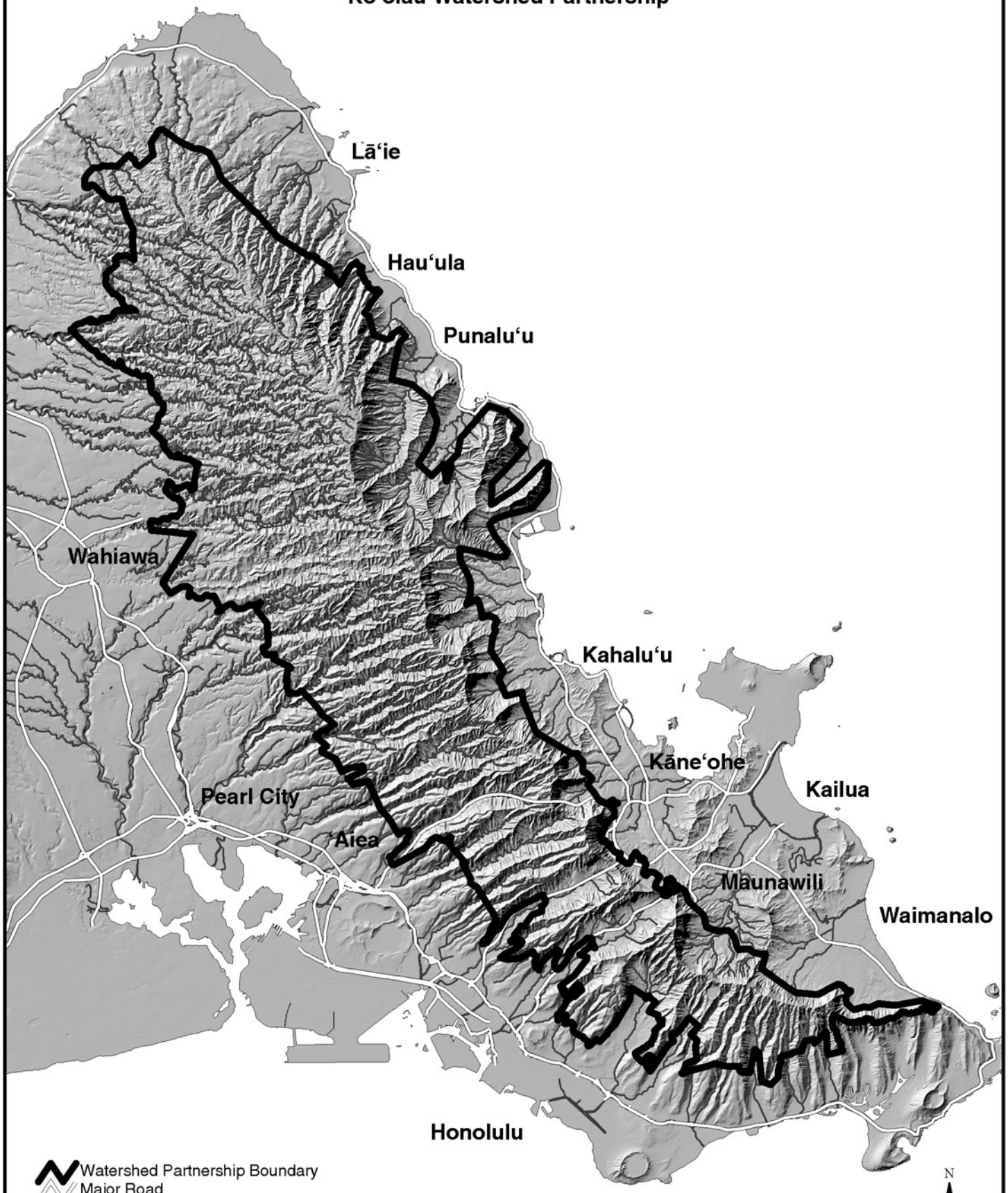
Map 1: General Location
Map 2: Hydrological Surface Features
Map 3: Biological Resources
Map 4: Land Ownership
Map 5: Population Density
Map 6: Percent of Owner-Occupied Dwellings
Map 7: Median Age

Overlay A: Water Resources
Overlay B: Land Ownership
Overlay C: Land Use Zones
Overlay D: Management Designations
Overlay E: Recreational Use and Resources

Map 1

General Location

Koʻolau Watershed Partnership

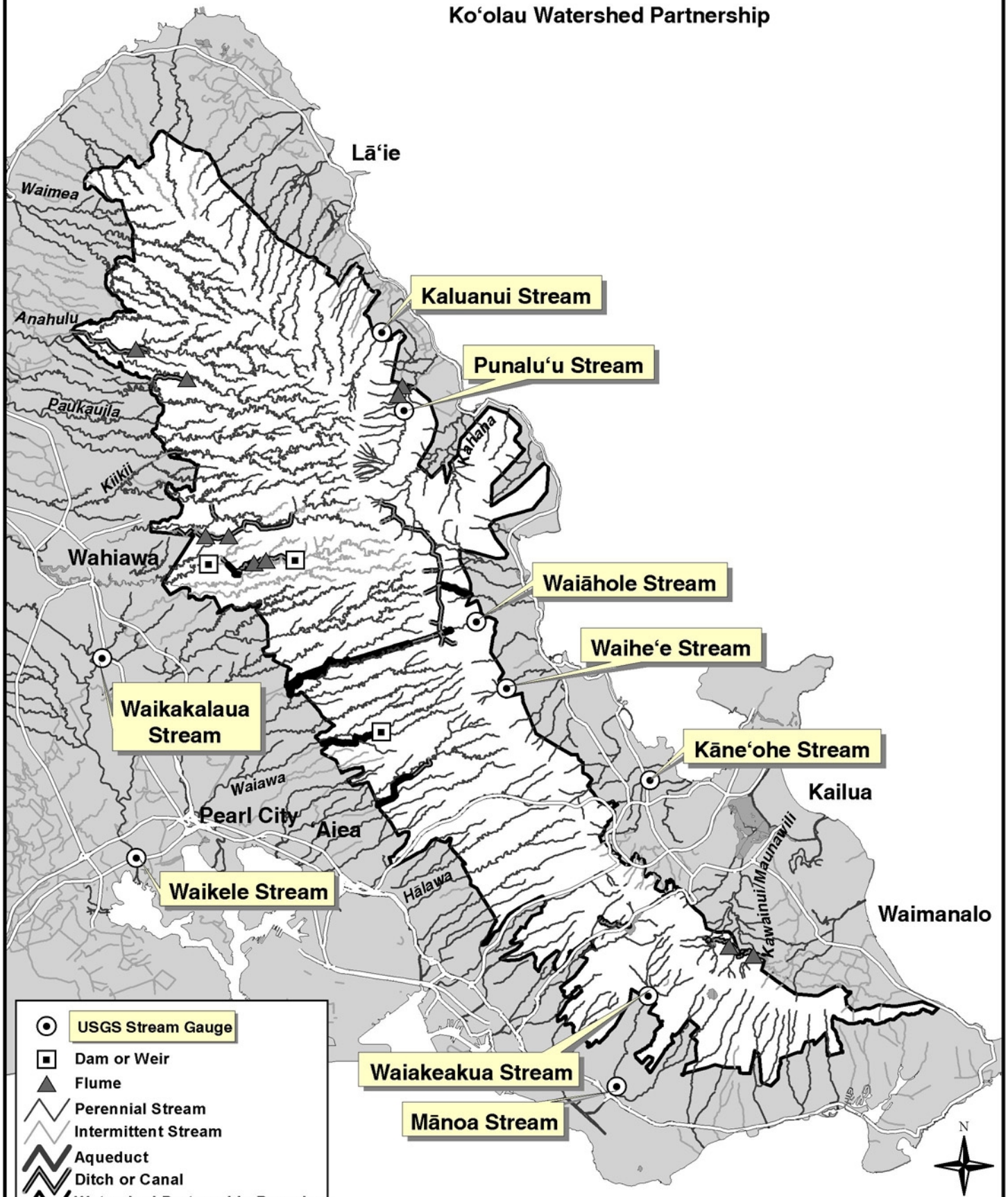


Produced by the Hawaiʻi Natural Heritage Program, November 2001.

Map 2

Hydrological Surface Features

Koʻolau Watershed Partnership

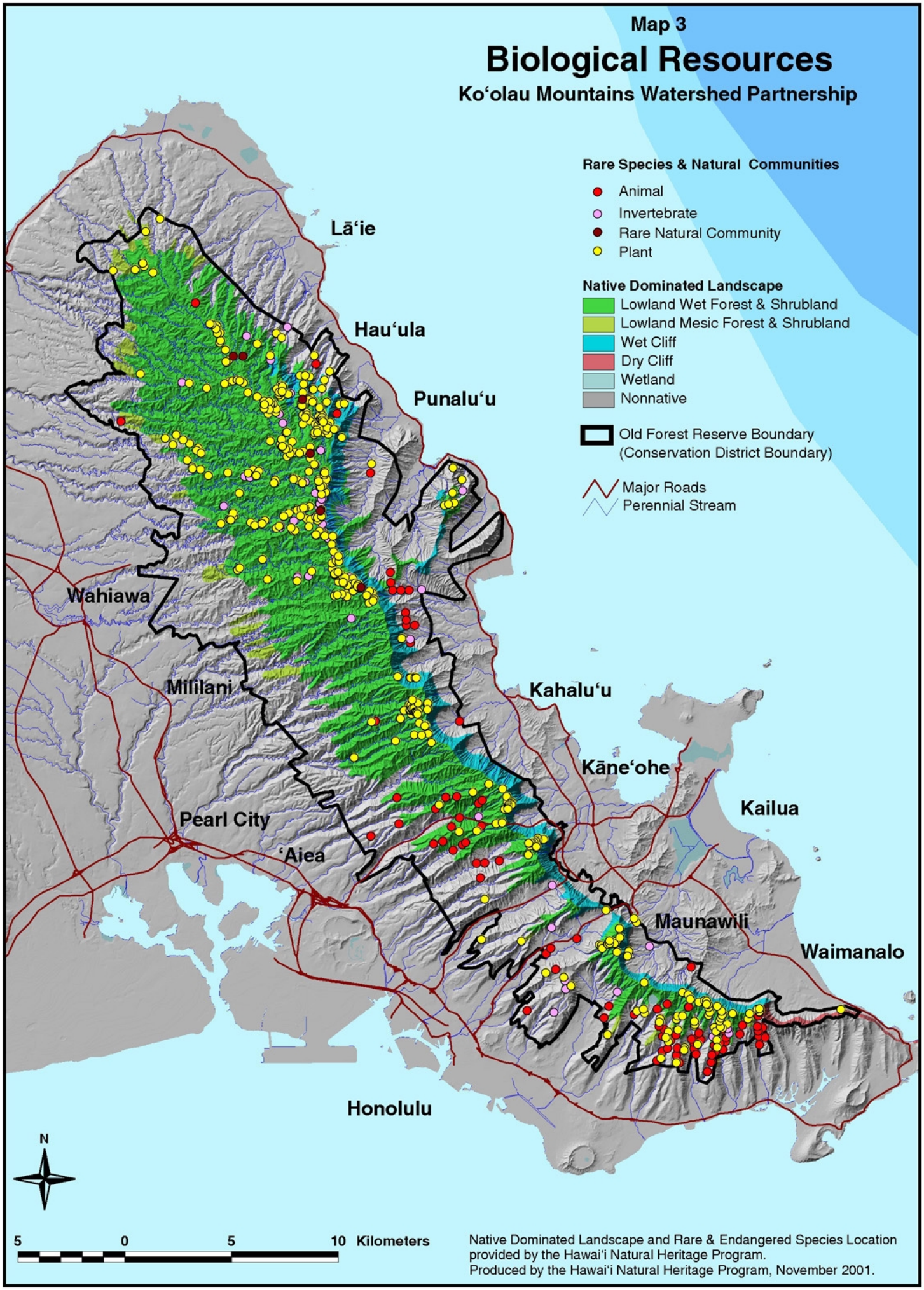


USGS Stream Gauge locations provided by National Water-Quality Assessment (NWQA) Program, U.S. Geological Services.
Stream Data Provided by the State of Hawaiʻi, Department of Business, Economic Development and Tourism.
Produced by the Hawaiʻi Natural Heritage Program, October 2001.

Map 3

Biological Resources

Koʻolau Mountains Watershed Partnership

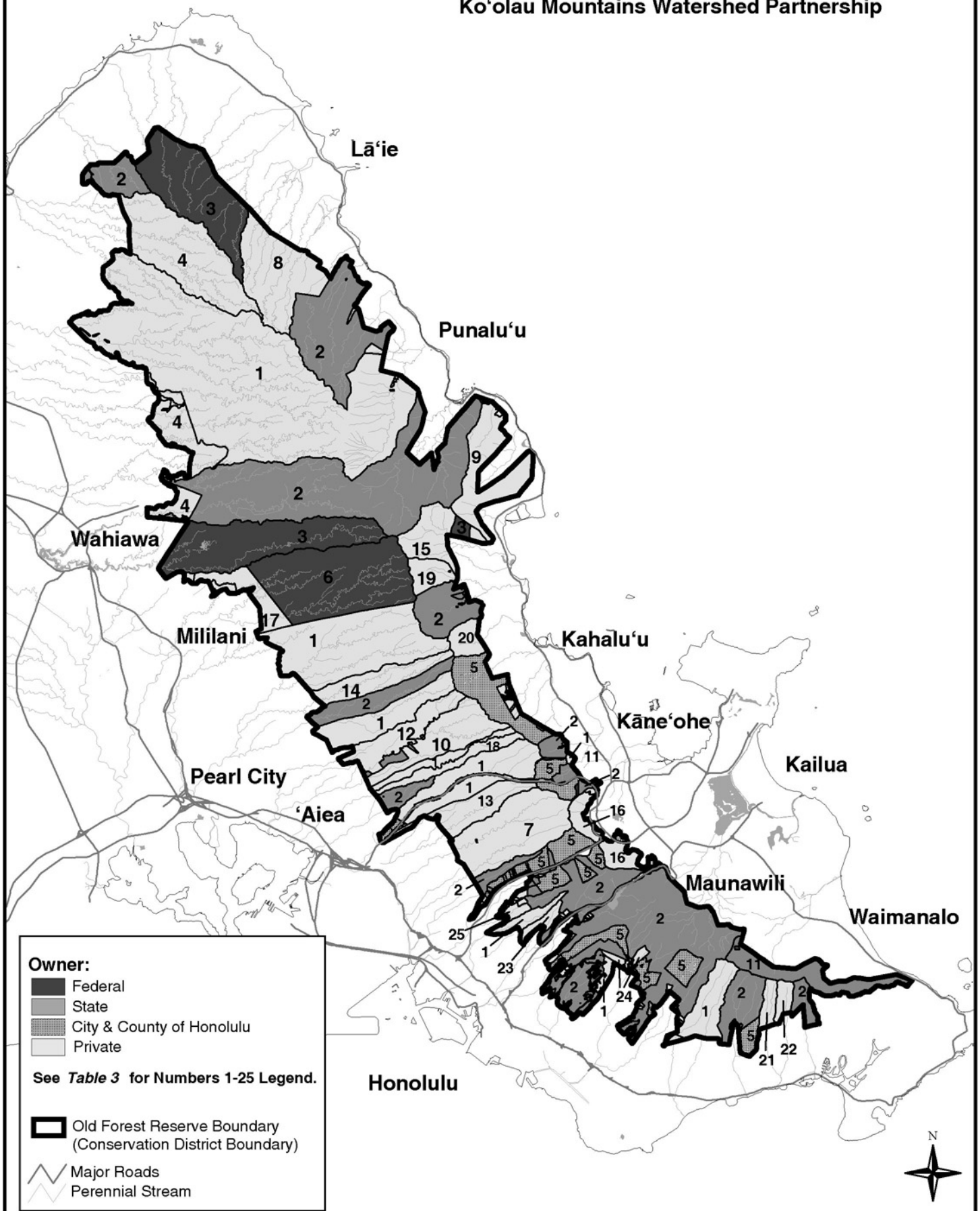


Native Dominated Landscape and Rare & Endangered Species Location provided by the Hawaiʻi Natural Heritage Program.
Produced by the Hawaiʻi Natural Heritage Program, November 2001.

Map 4

Land Ownership

Koʻolau Mountains Watershed Partnership

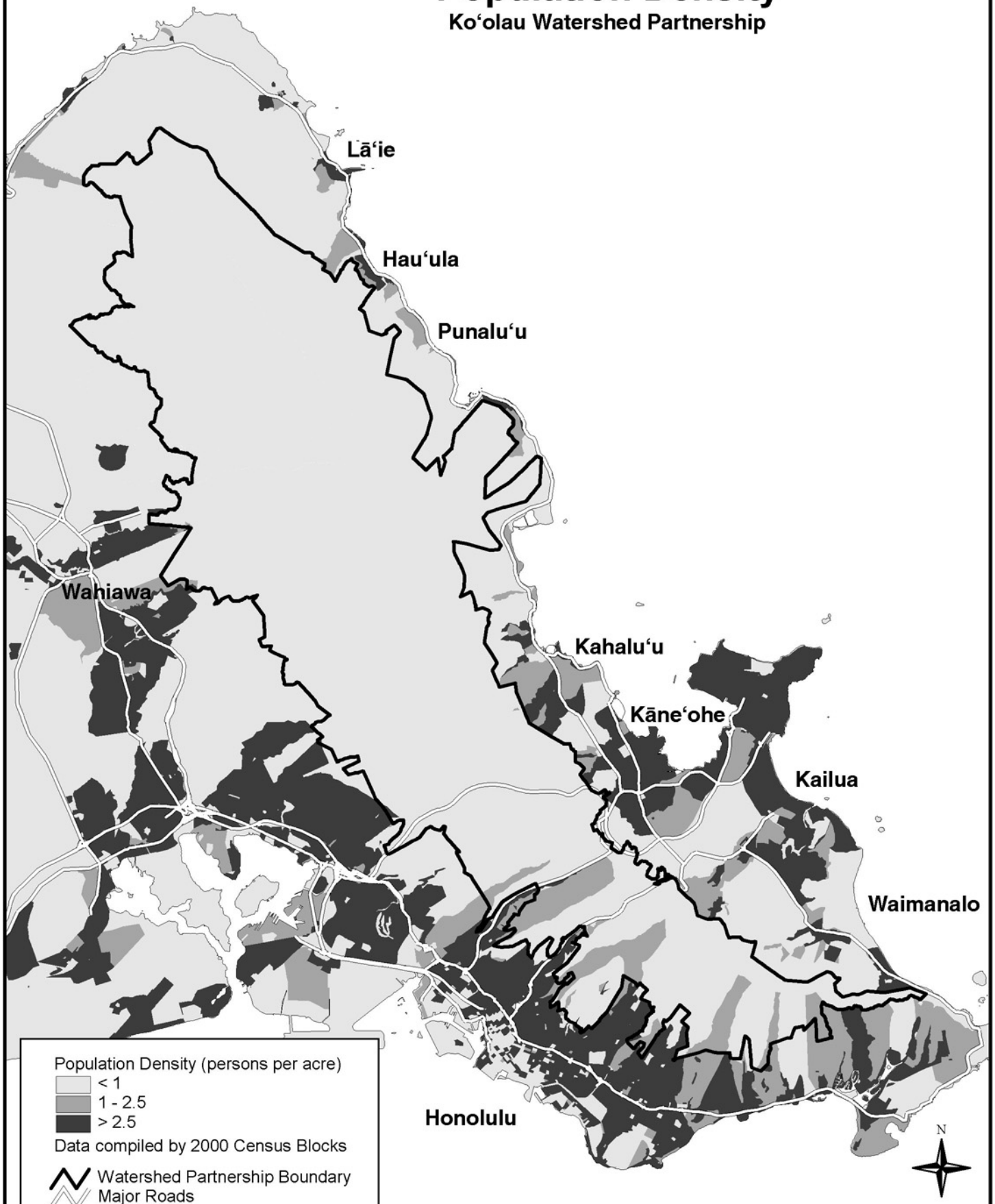


Ownership and Administrative Data Provided by the State of Hawaiʻi, Department of Land and Natural Resources, Division of Forestry and Wildlife.
Produced by the Hawaiʻi Natural Heritage Program, November 2001.

Map 5

Population Density

Koʻolau Watershed Partnership

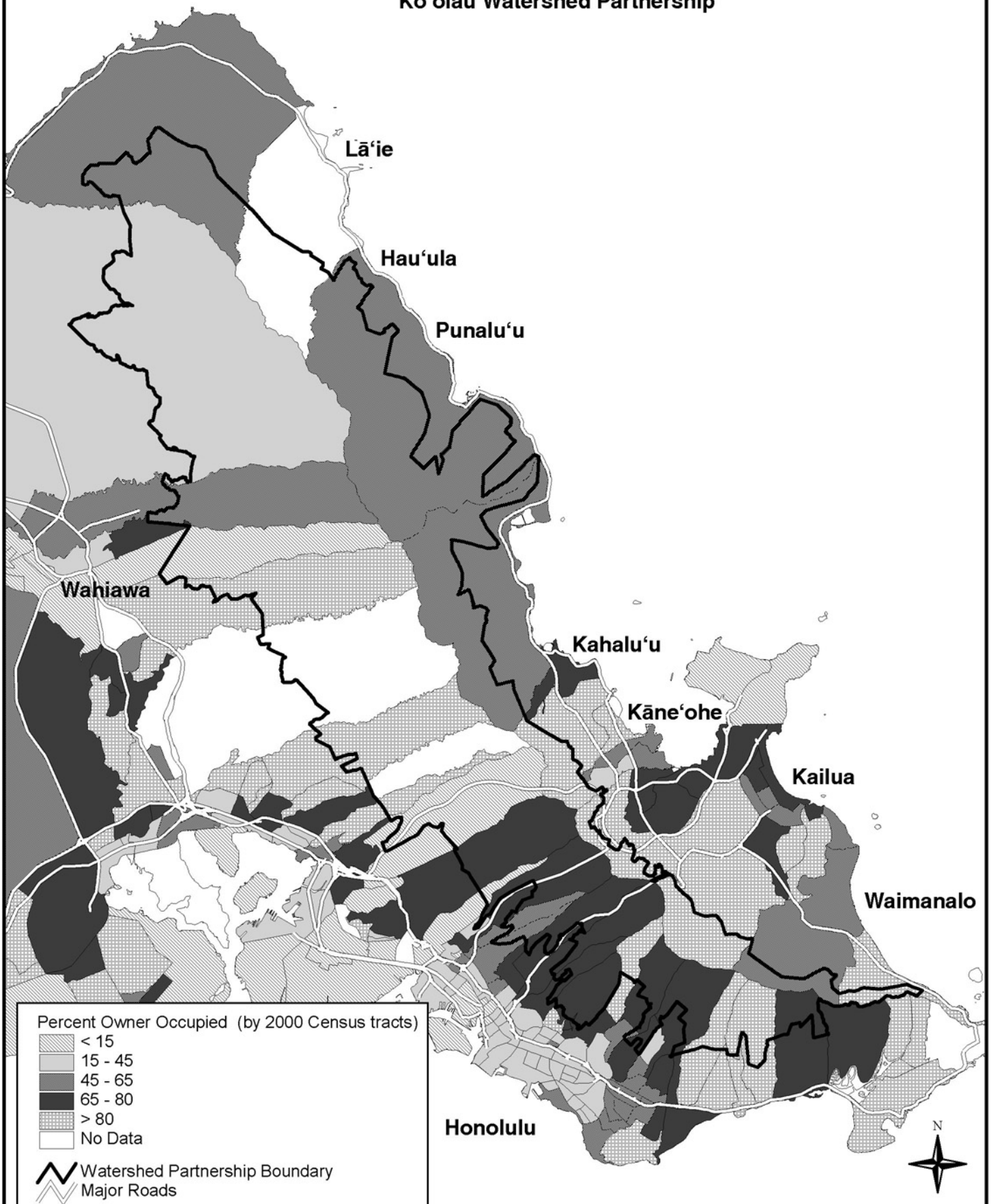


Census Data Provided by the State of Hawaiʻi, Department of Business, Economic Development and Tourism.
Produced by the Hawaiʻi Natural Heritage Program, November 2001.

Map 6

Percent of Owner-Occupied Dwellings

Koʻolau Watershed Partnership

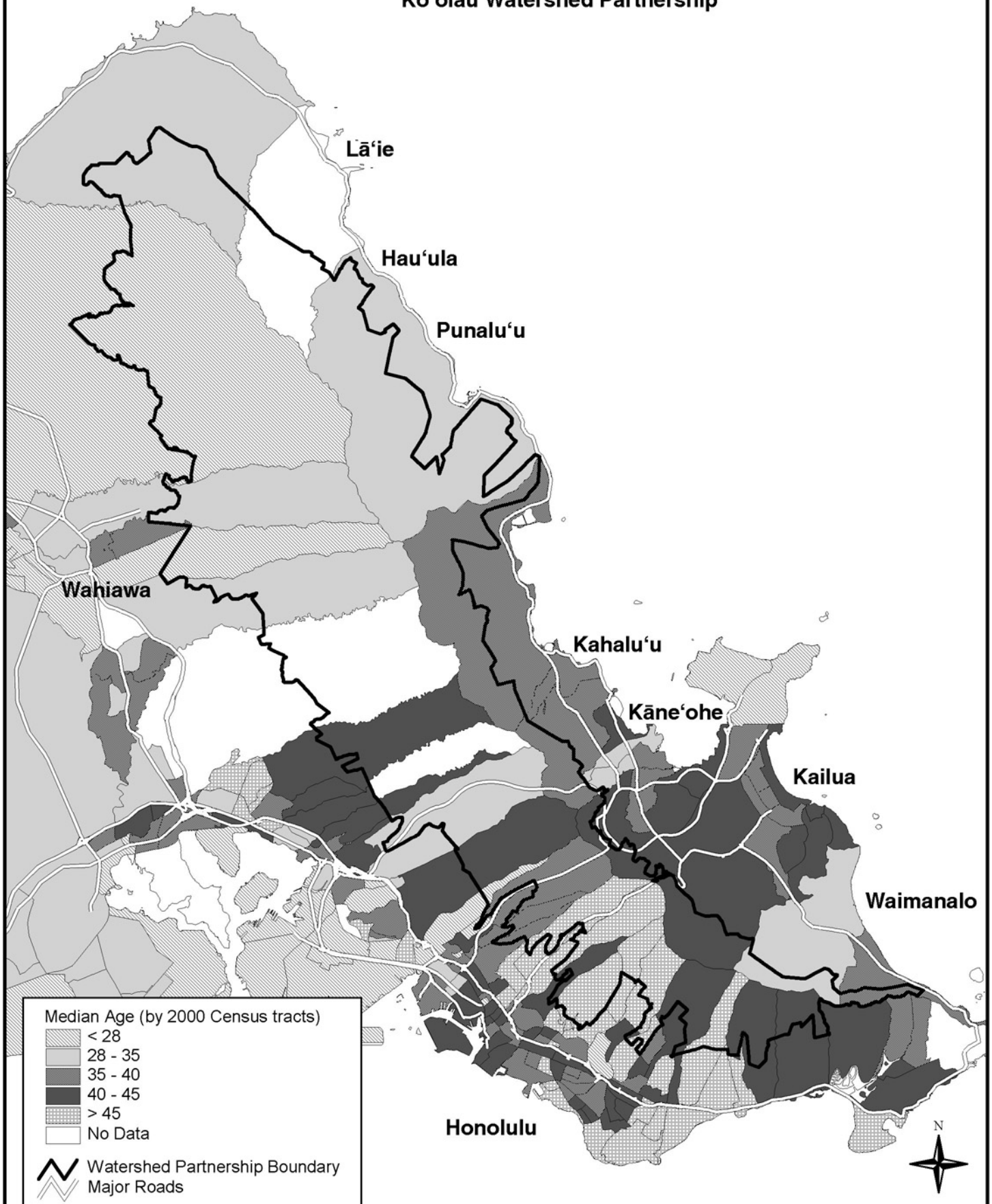


Census Data Provided by the U.S. Census Bureau,
U.S. Department of Commerce.
Produced by the Hawaiʻi Natural Heritage Program, November 2001.

Map 7

Median Age

Koʻolau Watershed Partnership



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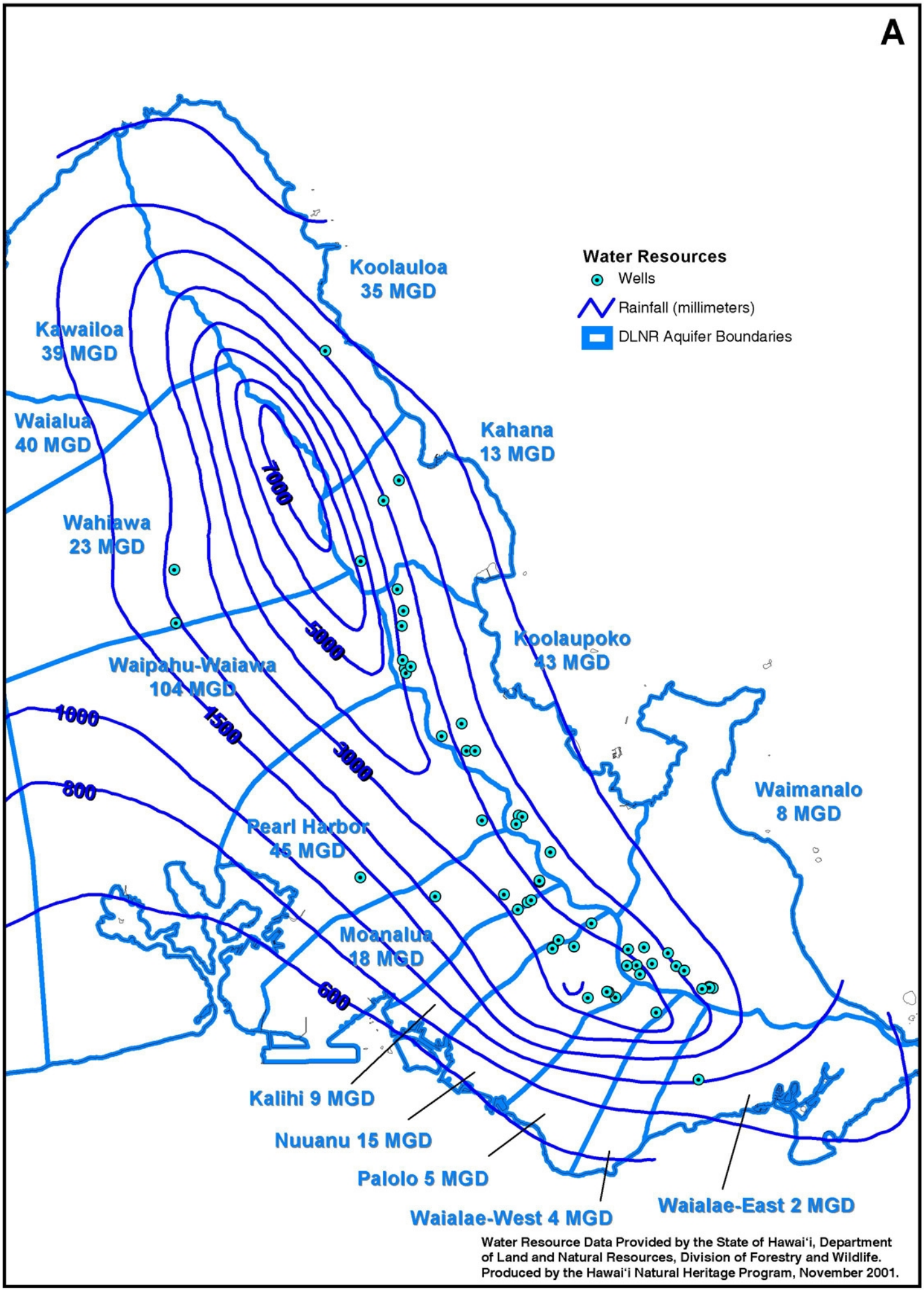
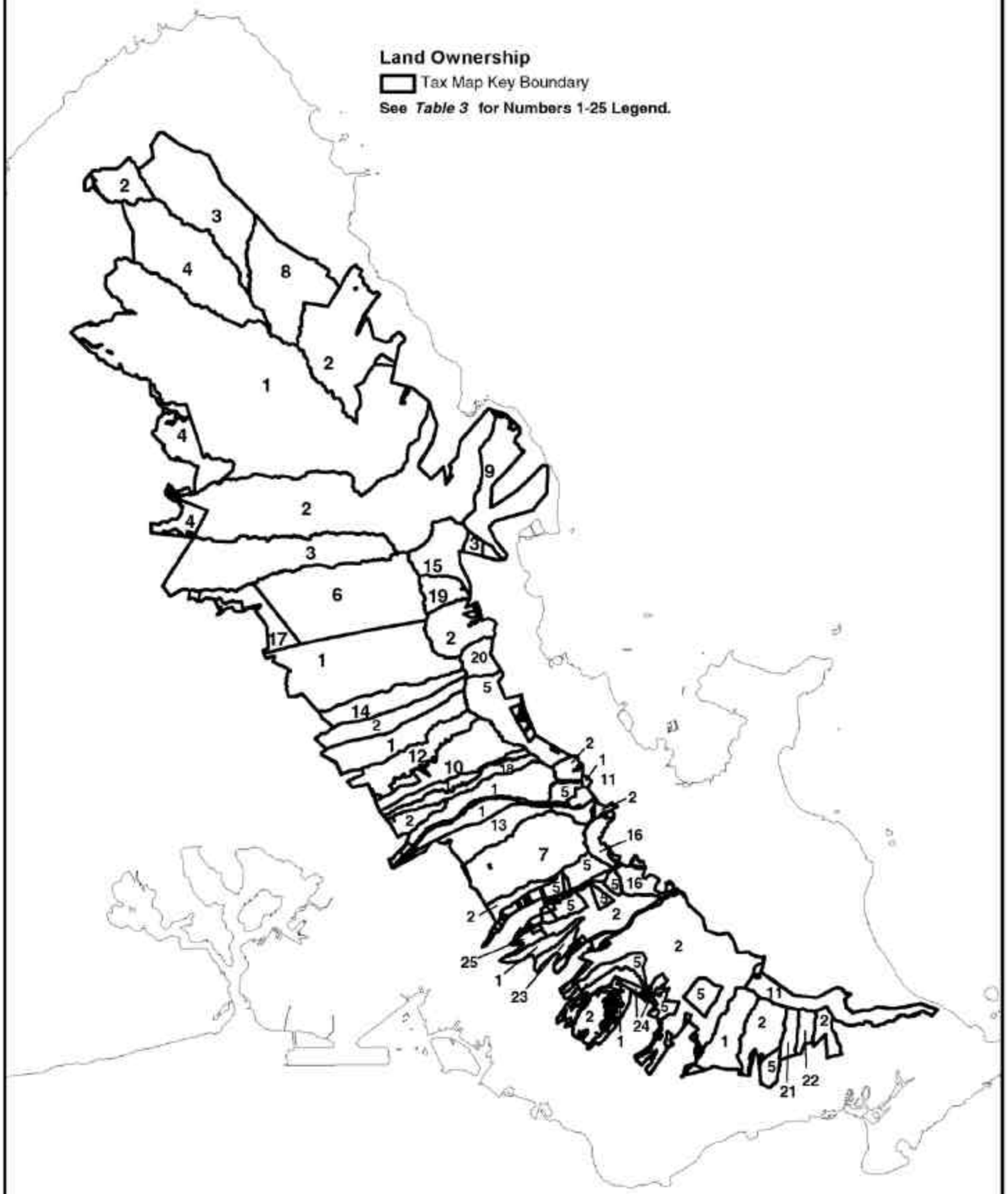
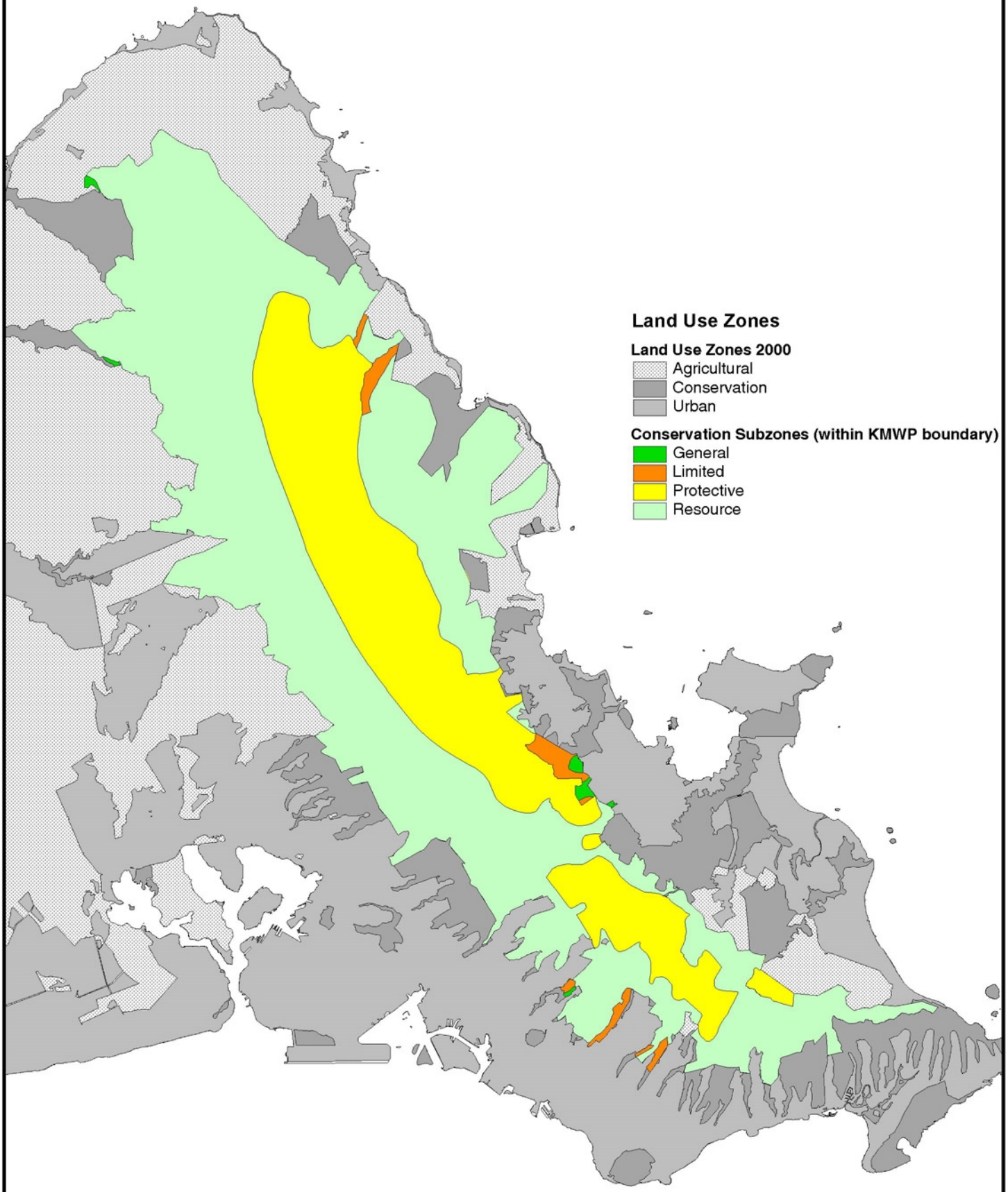

A
Water Resources
Wells
Rainfall (millimeters)
DLNR Aquifer Boundaries
Koolauloa
35 MGD
Kawailoa
39 MGD
Waialua
40 MGD
Kahana
13 MGD
Wahiawa
23 MGD
Koolaupoko
43 MGD
Waipahu-Waiawa
104 MGD
Waimanalo
8 MGD
Pearl Harbor
45 MGD
Moanalua
18 MGD
Kalihi 9 MGD
Nuuanu 15 MGD
Palolo 5 MGD
Waialae-West 4 MGD
Waialae-East 2 MGD
7000
5000
3000
1500
1000
800
600
Water Resource Data Provided by the State of Hawai'i, Department of Land and Natural Resources, Division of Forestry and Wildlife.
Produced by the Hawai'i Natural Heritage Program, November 2001.

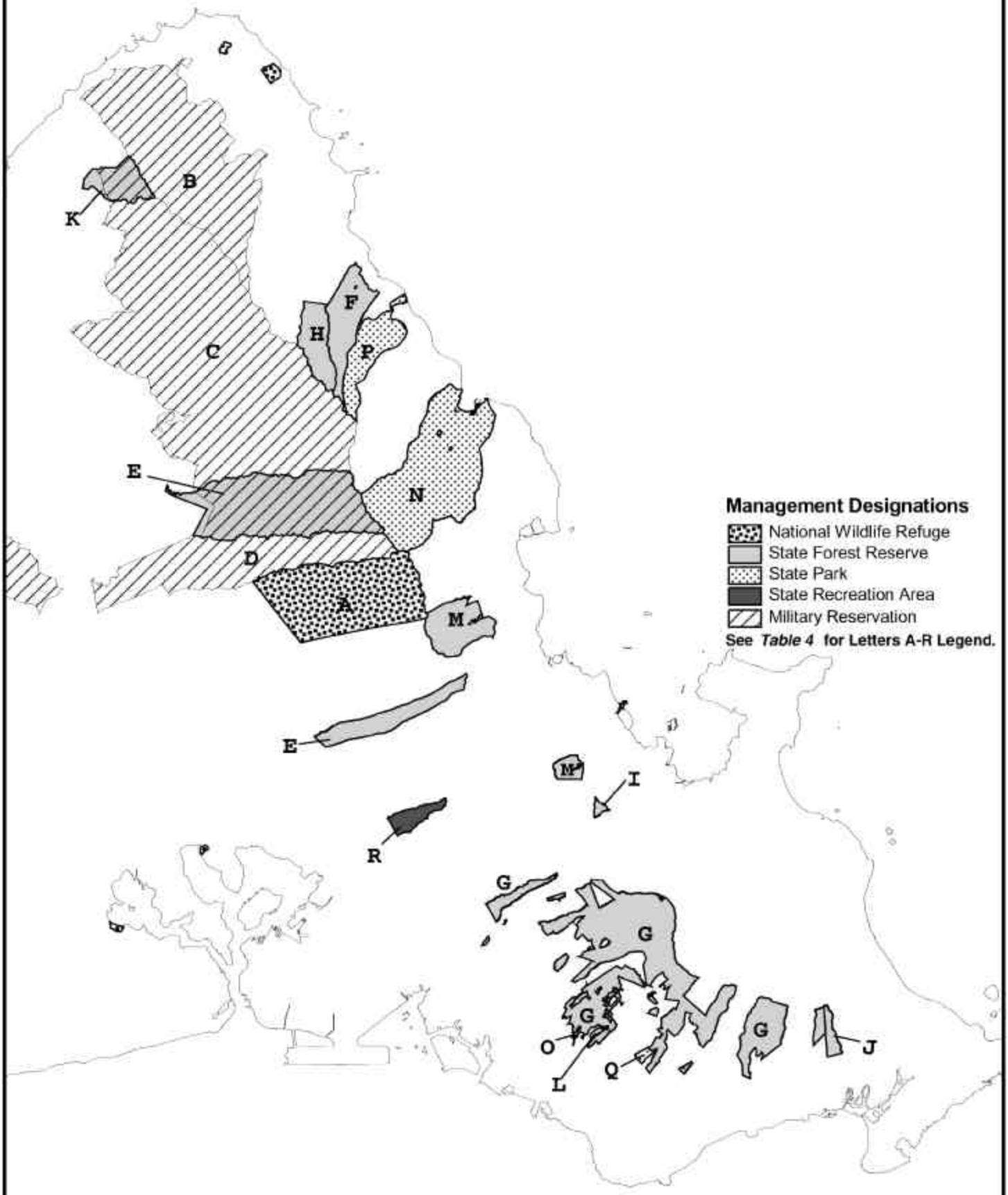
B


Land Ownership
Tax Map Key Boundary
See Table 3 for Numbers 1-25 Legend.

C



Land Use Data Provided by the State of Hawai'i, Department of Business, Economic Development and Tourism.
Produced by the Hawai'i Natural Heritage Program, November 2001.



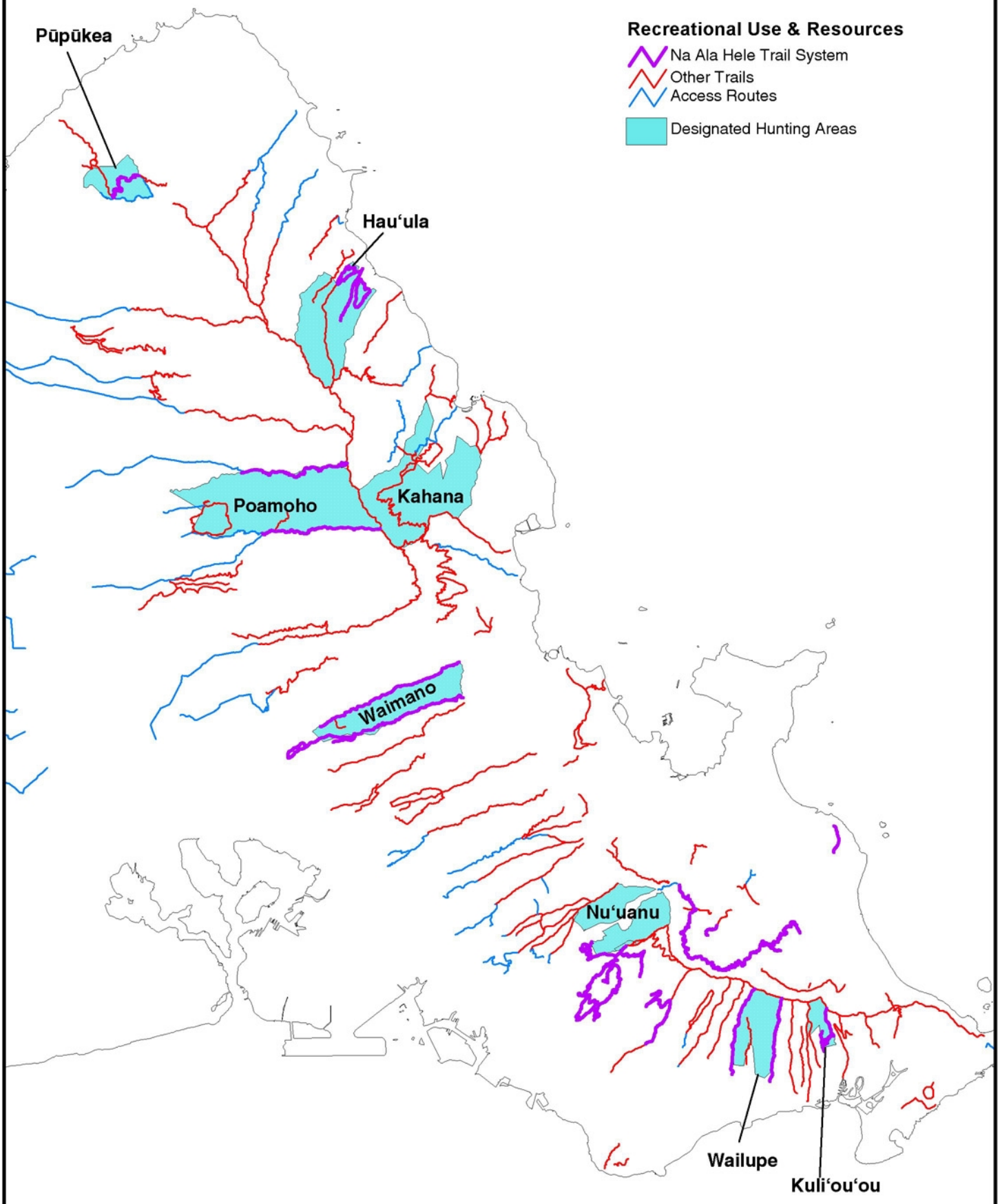
Management Designations

- National Wildlife Refuge
- State Forest Reserve
- State Park
- State Recreation Area
- Military Reservation

See *Table 4* for Letters A-R Legend.

Management designation provided by the State of Hawai'i, Department of Business, Economic Development and Tourism.
Produced by the Hawai'i Natural Heritage Program, November 2001.

E



Trail data provided by State of Hawai'i, Department of Land and Natural Resources, Division of Forest and Wildlife, Na Ala Hele.
Produced by the Hawai'i Natural Heritage Program, November 2001.

B. Rare Species and Natural Communities

Summary Table of Rare Species recorded within the Ko‘olau Mountains Watershed

	Listed Endangered	Candidate Species	Species of Concern	Ko‘olau Endemic Species
Plants	**37**	**4**	**27**	**34**
Animals	**24**	**8**	**4**	**16**

Federal Status

Official U.S. Fish and Wildlife Service, Endangered Species Act (ESA) categories for endangered and candidate endangered taxa (species, subspecies, and varieties) according to the Federal Register February 28, 1996.

LE (Listed Endangered) = Taxa formally listed as endangered.
C (Candidate) = Taxa for which substantial information on biological vulnerability and threat(s) support proposals to list them as endangered or threatened.
SOC (Species of Concern) = Taxa that available information does meet the criteria for concern and the possibility to recommend as candidate.

Heritage Global Ranks

The Global Rank (Grank) is an international ranking system developed by the Natural Heritage network. It determines the rarity of a species worldwide, and guides agencies to set priorities for protection. The ranking system is based on an element’s (taxa or ecosystem) number of occurrences and individuals, health, threats, etc. It is independent from the U.S. Fish and Wildlife Federal List of Endangered Species, but the USFWS often cites the Heritage Global Rank to help characterize the rare and imperiled status of a species.

G1 (or T1 for subspecific taxa) = Critically imperiled globally. 1-5 occurrences and/or fewer than 1,000 individuals remaining, or more abundant but facing extremely serious threats range-wide.
G2 (or T2 for subspecific taxa) = Imperiled globally. 6-20 occurrences and/or 1,000-3,000 individuals remaining, or more abundant but facing serious threats range-wide.
G3 (or T3 for subspecific taxa) = Moderately imperiled globally. 21-100 occurrences and/or 3,000-10,000 individuals remaining; or more abundant but facing moderate threats range-wide; or restricted in range.
G4 (or T4 for subspecific taxa) = Widespread, abundant, and apparently secure, but with cause for long-term concern.
G5 (or T5 for subspecific taxa) = Demonstrably widespread, abundant, and secure.
GH (or TH for subspecific taxa) = Historical. No recent observations, but there remains a chance of rediscovery.

Y = Yes, endemic to Ko‘olau Mountains watershed
Y* = Yes, currently known only from Ko‘olau Mountains watershed but was historically found elsewhere.

Note: Global rank assignments for the insects, and for many of the snails (other than *Achatinella*) listed in this appendix are tentative. While the Hawai’i Natural Heritage Program has some information in its database about these taxa, they are not actively tracked.

List of Rare Species and Natural Communities recorded within the Ko'olau Mountains Watershed

Based on Report Prepared by the Hawai'i Natural Heritage Program, 2000

(updated January 2002 based on review by Joel Lau)

Scientific Name	Common Name	Federal Status	Global Rank	Endemic
Animal-Vertebrates				
ANAS WYVILLIANA	HAWAIIAN DUCK, KOLOA	LE	G1	
CHASIEMPIS SANDWICHENSIS IBIDIS	OAHU 'ELEPAIO	LE	G4T1T2	
FULICA ALAI	'ALAE KE'OKE'O, HAWAIIAN COOT	LE	G2	
GALLINULA CHLOROPUS SANDVICENSIS	HAWAIIAN GALLINULE, 'ALAE-'ULA	LE	G5T2	
LASIURUS CINEREUS SEMOTUS	'OPE'APE'A, HAWAIIAN HOARY BAT	LE	G5T2	
PAROREOMYZA MACULATA	O'AHU 'ALAUAHIO, O'AHU CREEPER	LE	G1	
PSITTIROSTRA PSITTACEA	'O'U	LE	G1	
VESTIARIA COCCINEA (O'AHU ONLY)	'I'IWI		G4T1	
Animal-Invertebrates				
ACHATINELLA APEXFULVA	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA BELLULA	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA BULIMOIDES	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA BYRONII	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA CURTA	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA DECIPIENS	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA FULGENS	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA FUSCOBASIS	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA LEUCORRAPHE	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA LILA	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA LIVIDA	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA PULCHERRIMA	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA PUPUKANIOE	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA SOWERBYANA	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA STEWARTII	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
ACHATINELLA VIRIDANS	O'AHU TREE SNAIL, PUPU KUAHIWI	LE	G1	Y
AURICULELLA DIAPHANA	ACHATINELLID LAND SNAIL		G?	
AURICULELLA PERPUSILLA	ACHATINELLID LAND SNAIL		G1	
AURICULELLA PULCHRA	ACHATINELLID LAND SNAIL		G1	
AURICULELLA TENUIS	ACHATINELLID LAND SNAIL		G?	
DROSOPHILA HEMIPEZA	POMACE FLY	C	G1	
DROSOPHILA OBATAI	POMACE FLY	C	G1	
DROSOPHILA SUBSTENOPTERA	POMACE FLY	C	G1	
HEDYLEPTA MONOGRAMMA	(MOTH)		G1	
LEPTACHATINA SP 8	AMASTRID LAND SNAIL	SOC	G1	
MANDUCA BLACKBURNI	BLACKBURN'S SPHINX MOTH	LE	G1	
MEGALAGRION ADYTUM	ADYTUM MEGALAGRION DAMSELFLY	SOC	G1G3	
MEGALAGRION LEPTODEMAS	CRIMSON HAWAIIAN DAMSELFLY	C	G1	
MEGALAGRION NIGROHAMATUM NIGROLINEATUM	BLACKHOOK HAWAIIAN DAMSELFLY	C	G4T2	
MEGALAGRION OAHUENSE	OAHU MEGALAGRION DAMSELFLY	SOC	G1G3	
MEGALAGRION OCEANICUM	OCEANIC MEGALAGRION DAMSELFLY	C	G2	
MEGALAGRION PACIFICUM	PACIFIC MEGALAGRION DAMSELFLY	C	G2	

MEGALAGRION XANTHOMELAS	ORANGE-BLACK MEGALAGRION DAMSELFLY	C	G1G3	
PENTARTHRUM OBSCURUM	OBSCURE PENTARTHRUM WEEVIL	SOC	G1	
Natural Communities				
METROSIDEROS POLYMORPHA MIXED MONTANE BOG	ʻOHIʻA MIXED MONTANE BOG		G2	
PRITCHARDIA MARTII LOWLAND WET FOREST	LOULU HIWA LOWLAND WET FOREST		G2	
Plants				
ACACIA KOAIA	KOAIʻA, KOAIʻE	SOC	G2	
BIDENS CAMPYLOTHECA SSP CAMPYLOTHECA	KOʻOKOʻOLAU, KOKOʻOLAU	SOC	G2T2	
BIDENS POPULIFOLIA	KOʻOKOʻOLAU, KOKOʻOLAU	SOC	G1	Y
BOBEA SANDWICENSIS	ʻAHAKEA		G1	
BOBEA TIMONIOIDES	ʻAHAKEA	SOC	G1	
BONAMIA MENZIESII		LE	G1	
CAREX WAHUENSIS SSP HERBSTII		SOC	G3	Y
CHAMAESYCE ARNOTTIANA	ʻAKOKO, KOKO, KOKOMALEI	SOC	G1	
CHAMAESYCE DEPPEANA	ʻAKOKO, KOKO, KOKOMALEI	LE	G1	Y
CHAMAESYCE ROCKII		LE	G1	Y
CYANEA ACUMINATA	ʻOHA, HAHA, ʻOHA WAI	LE	G2	
CYANEA CALYCINA	ʻOHA, HAHA, ʻOHA WAI	SOC*	G1	
CYANEA CRISPA	ʻOHA, HAHA, ʻOHA WAI	LE	G1	Y
CYANEA GRIMESIANA SSP GRIMESIANA	ʻOHA, HAHA, ʻOHA WAI	LE	G1T1	
CYANEA HUMBOLDTIANA	ʻOHA, HAHA, ʻOHA WAI	LE	G1	Y
CYANEA KOOLAUENSIS		LE	G1	Y
CYANEA LANCEOLATA	ʻOHA, HAHA, ʻOHA WAI	SOC*	G1	Y
CYANEA PURPURELLIFOLIA	ʻOHA, HAHA, ʻOHA WAI	SOC	G1	Y
CYANEA ST.-JOHNII	ʻOHA, HAHA, ʻOHA WAI	LE	G1	Y
CYANEA TRUNCATA	ʻOHA, HAHA, ʻOHA WAI	LE	G1	Y
CYRTANDRA DENTATA	HAʻIWALE, KANAWAO KEʻOKEʻO	LE	G1	
CYRTANDRA GRACILIS	HAʻIWALE, KANAWAO KEʻOKEʻO	SOC	GH	Y
CYRTANDRA KAULANTHA	HAʻIWALE, KANAWAO KEʻOKEʻO	SOC*	G1	Y
CYRTANDRA POLYANTHA	HAʻIWALE, KANAWAO KEʻOKEʻO	LE	G1	Y
CYRTANDRA SANDWICENSIS	HAʻIWALE, KANAWAO KEʻOKEʻO	SOC	G1	Y
CYRTANDRA SESSILIS	HAʻIWALE, KANAWAO KEʻOKEʻO	C*	G1	Y
CYRTANDRA SUBUMBELLATA	HAʻIWALE, KANAWAO KEʻOKEʻO	LE	G1	Y
CYRTANDRA VIRIDIFLORA	HAʻIWALE, KANAWAO KEʻOKEʻO	LE	G1	Y
CYRTANDRA WAIOLANI	HAʻIWALE, KANAWAO KEʻOKEʻO	SOC	G1	Y
DIELLIA ERECTA		LE	G1	
DOODIA LYONII			G1	
EUGENIA KOOLAUENSIS	NIOI	LE	G1	
EURYA SANDWICENSIS	ANINI, WANINI	SOC	G2	
EXOCARPOS GAUDICHAUDII	HEAU	SOC	G1	
GARDENIA MANNII	NANU, NAʻU	LE	G1	
HEDYOTIS FLUVIATILIS		SOC*	G1	
HESPEROMANNIA ARBORESCENS		LE	G1	
HIBISCUS KOKIO SSP KOKIO	KOKIʻO ʻULAʻULA	SOC	G2T2	
ISODENDRION LONGIFOLIUM	AUPAKA	LE	G2	
JOINVILLEA ASCENDENS SSP ASCENDENS	ʻOHE	SOC*	G5T1	
LABORDIA CYRTANDRAE	KAMAKAHALA	LE	G1	
LEPIDIUM BIDENTATUM VAR O-WAIHIENSE	ʻANAUNAU, NAUNAU, KUNANA	SOC	G5T2	
LINDSAEA REPENS VAR MACRAEANA		SOC	G5T2	
LIPOCHAETA LOBATA VAR LOBATA	NEHE		G2T2	
LOBELIA GAUDICHAUDII SSP GAUDICHAUDII	ʻOHA, HAHA, ʻOHA WAI	SOC	G1T1	

LOBELIA GAUDICHAUDII SSP KOOLAUENSIS	‘OHA, HAHA, ‘OHA WAI	LE	G1T1	Y
LOBELIA MONOSTACHYA	‘OHA, HAHA, ‘OHA WAI	LE	G1	Y
LOBELIA OAHUENSIS	‘OHA, HAHA, ‘OHA WAI	LE	G1	Y
LYSIMACHIA FILIFOLIA		LE	G1	
MARSILEA VILLOSA	‘IHI ‘IHI, ‘IHI LA‘AU	LE	G1	
MELICOPE HIIAKAE		C	G1	Y
MELICOPE LYDGATEI	ALANI	LE	G1	Y
MYRSINE FOSBERGII	KOLEA	SOC*	G1	
MYRSINE JUDDII	KOLEA	LE	G1	Y
NERAUDIA MELASTOMIFOLIA	MA‘ALOA, MA‘OLOA, ‘OLOA	SOC	G2	
NESOLUMA POLYNESICUM	KEAHI	SOC	G2	
PHLEGMARIURUS NUTANS		LE	G1	Y*
PHYLLOSTEGIA HIRSUTA		LE	G1	
PHYLLOSTEGIA PARVIFLORA VAR PARVIFLORA		LE	G1T	Y
PLANTAGO PRINCEPS VAR. PRINCEPS	ALE	LE	G1	
PLATYDESMA CORNUTA VAR CORNUTA	PILO KEA	SOC*	G2T1	Y
PSYCHOTRIA HEXANDRA VAR OAHUENSIS	KOPIKO, ‘OPIKO	C*	G3T1	Y
PTERALYXIA MACROCARPA	KAULU	SOC*	G1	
PTERIS LYDGATEI		LE	G1	
SANICULA PURPUREA		LE	G1	
SCHIEDEA GLOBOSA			G2	
SCHIEDEA KAALAE		LE	G1	
STENOGYNE KAALAE SSP SHERFFII			G1	Y
TETRAPLASANDRA GYMNOCARPA		LE	G1	Y
THELYPTERIS BOYDIAE		SOC*	G1	
TREMATOLOBELIA SINGULARIS		LE	G1	Y
VIOLA OAHUENSIS		LE	G1	Y
ZANTHOXYLUM OAHUENSE	HEA‘E, A‘E	C*	G1	Y

Historical Occurrences

These species have not been observed in the area in the past 15 years; however, there is a possibility of rediscovery with further survey.

Scientific Name	Common Name	Federal Status	Global Rank	Endemic
Animal-Invertebrates				
ACHATINELLA ABBREVIATA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA CESTUS	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA DIMORPHA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA ELEGANS	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA JUDDII	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA JUNCEA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA LORATA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA PHAEOZONA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA ROSEA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA SWIFTII	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA TAENIOLATA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA TURGIDA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA VALIDA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA VITTATA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
ACHATINELLA VULPINA	OAHU TREE SNAIL, PUPU KUAHIWI	LE	GH	Y
NESOPROSOPIS UNICA	UNIQUE YELLOW-FACED BEE	SOC	GH	

Plants

ADENOPHORUS PERIENS		LE	G1	
ALECTRYON MACROCOCCUS VAR MACROCOCCUS	ʻALAʻALAHUA, MAHOE	LE	G1T1	
BOTRYCHIUM SUBBIFOLIATUM	MAKOU	SOC	GH	
CAESALPINIA KAVAIENSIS	UHIUHI	LE	G1	
CLERMONTIA MULTIFLORA	ʻOHA, ʻOHA WAI	SOC	GH	
CTENITIS SQUAMIGERA	PAUOA	LE	G1	
CYANEA LONGIFLORA	ʻOHA, HAHA, ʻOHA WAI	LE	G1	
CYANEA SP 3			G1	
CYANEA SUPERBA SSP REGINA	ʻOHA, HAHA, ʻOHA WAI	LE	G1TH	
CYANEA TRUNCATA	ʻOHA, HAHA, ʻOHA WAI	LE	G1	
CYRTANDRA CRENATA	HAʻIWALE, KANAWAO KEʻOKEʻO	LE	GH	Y
CYRTANDRA PRUINOSA	HAʻIWALE, KANAWAO KEʻOKEʻO	SOC	GH	Y
DELISSEA LACINIATA	ʻOHA, HAHA, ʻOHA WAI	SOC	GH	Y
DELISSEA LAULIIANA	ʻOHA, HAHA, ʻOHA WAI	SOC	GH	Y
DELISSEA SUBCORDATA	ʻOHA, HAHA, ʻOHA WAI	LE	G1	
DIELLIA FALCATA		LE	G2	
GARDENIA BRIGHAMII	NANU, NAʻU	LE	G1	
HEDYOTIS CORIACEA		LE	G1	
HEDYOTIS ELATIOR		SOC	G1	
ISODENDRION LAURIFOLIUM	AUPAKA	LE	G1	
KOKIA LANCEOLATA	KOKIʻO		GH	Y
LYSIMACHIA FORBESII		SOC	GH	Y
MELICOPE CINEREA	ALANI		G1	
MELICOPE SAINT-JOHNII	ALANI	LE	G1	
NOTHOCESTRUM LATIFOLIUM	ʻAIEA	SOC	G1	
PHYLLOSTEGIA MOLLIS		LE	G1	
PLANTAGO PRINCEPS VAR LONGIBRACTEATA	ALE	LE	G2T1	
PLATANTHERA HOLOCHILA		LE	G1	
PLEOMELE FORBESII	HALAPEPE	C*	G1	
PSYCHOTRIA HEXANDRA VAR HOSAKANA	KOPIKO, ʻOPIKO		G3TH	Y
PSYCHOTRIA HEXANDRA VAR ROCKII	KOPIKO, ʻOPIKO		G3TH	Y
SCHIEDEA NUTTALLII		LE	G1	
SOLANUM SANDWICENSE	POPOLOʻAIAKEAKUA	LE	G1	
VIGNA O-WAHUENSIS		LE	G1	

C. Invasive Weed Species

Plant species (common name) Incipient Species are highlighted in **bold**	**Major Areas of Infestation**	**Plant characteristics**				
		Form	**Range**	**Fire**	**Other problems**	**Other Uses/ Comments**
Andropogon virginicus (broomsedge)	O‘ahu	Perennial bunchgrass	Dry to mesic environment, with high sunlight.	Fire stimulated.	Dormant during rainy season; contributes to erosion and high runoff.	None.
Casuarina glauca (common ironwood)	O‘ahu; large population in Nu‘uanu	Large, fast-growing tree, up to 40 m or more	Common in all but the driest and wettest coastal areas up to 500 m.	Regenerates rapidly from basal shoots after fire. The lack of undergrowth prevents intense fires.	Forms monotypic stands under which little else grows; allelopathy suspected.	Wind-dispersed seeds. Planted for windbreaks, erosion control, and nitrogen fixation.
Citharexylum spinosum (**fiddlewood**)	Tantalus, Pūpūkea, Waimānalo	Evergreen, medium-sized tree	It grows in dry habitats generally below 500 m.	Fire response in Hawai‘i is unknown.	Forms crowded stands even in undisturbed habitats.	Dispersed by alien frugivorous birds, Deciduous during dry season.
Clidemia hirta (Koster’s curse)	O‘ahu	Weedy shrub to 2 m.	All.	Not fire resistant; is pioneering.	Shades competition; aggressive invader.	None. May be spread in conjunction with marijuana growing.
Hedychium gardnerianum (kahili ginger)	O‘ahu	Showy ginger, grows to just over 1 m tall.	Wet habitats between sea level and 1,700 m.	Adaptation to fire is unknown; however, will recover unless fire harms rhizomes.	Each plant grows rapidly by stolons, displacing all other plants.	Seed dispersed by alien, and perhaps native, frugivorous birds and humans.
Lantana camara (lantana)	O‘ahu	Thorny shrub	0–600 m, dry areas.	Survives all but hottest fires.	Forms impenetrable thickets; allelopathic.	None.
Leptospermum scoparium (**New Zealand tea, *manuka*)**	above Lā‘ie	Small, scrubby tree	Mesic habitats between 300-700 m elevation.	Fire response in Hawai‘i has not been established.	Forms thickets which crowd out other plants; allelopathy suspected.	Wind dispersed seeds.
Leucaena leucocephala (*koa haole*)	O‘ahu	Small tree	0–700 m	Fire may flush new seedlings; mature stands suppress fire.	Dense thickets exclude other species; regenerates rapidly after fire.	Used for fodder. Deliberately introduced on wide scale.
Melinis minutiflora (molasses grass)	O‘ahu	Perennial mat grass	0–1500 m in dry and mesic environments.	Fire adapted.	Smothers competitors, spreads quickly.	Good forage grass.

Plant species (common name) Incipient Species are highlighted in **bold**	**Major Areas of Infestation**	**Plant characteristics**				
		Form	**Range**	**Fire**	**Other problems**	**Other Uses/ Comments**
Miconia calvescens **(purple velvet leaf)**	Kahili, Mānoa,	Tree to 15 meters	Mesic to wet habitats.	None.	Creates dense monotypic stands. Seed production frequent and large.	Brought in for ornamental purposes.
Myrica faya **(faya tree)**	Palikea Ridge	Tree to 15 meters	300–1700 m, invades mesic, wet habitats.	Not fire adapted.	Forms dense monotypic stands; nitrogen fixer.	None.
Panicum maximum (Guinea grass)	O‘ahu	Coarse, perennial grass, > 2 m.	Dry areas between sea level and 1,200 m.	Burn easily, but will regenerate rapidly from underground rhizomes.	Strong allelopathic activity, can survive long periods of drought.	Wind dispersed seeds.
Pennisetum clandestinum (kikuyu grass)	None	Rhizomatous	500–2000 m in dry and mesic habitats and wet disturbed habitats.	Slow burning. Fire retardant.	Noxious weed classification. Strong allelopathy.	Favored rangeland grass.
Pennisetum setaceum **(fountain grass)**	Diamond Head, Punchbowl	Bunchgrass	Dry habitats.	Fire stimulated. Carries intense fires throughout range.	Crowds out other species.	Bio-control opposed by sugar interests.
Psidium cattleianum (strawberry guava)	O‘ahu	Medium size tree	Mesic and wet habitats.	Unknown.	Forms dense monotypic thickets; found in conjunction with pig disturbance.	None.
Psidium guajava (common guava)	O‘ahu	Evergreen tree, up to 8 m.	Mesic to wet areas below 500 m and in gulches; even in dry areas.	Can survive moderately intense fires by regenerating from basal sprouts.	Invades disturbed sites and forms dense thickets. Leaves suspected of allelopathy.	Seeds are dispersed by alien frugivorous birds as well as rats and feral pigs.
Rhodomyrtus tomentosa **(downy rose-myrtle)**	?	Evergreen shrub, rarely above 3 m.	Lowland mesic habitats.	Unknown.	Forms dense thickets.	Seeds dispersed by alien frugivorous birds.
Rubus argutus (prickly Florida blackberry)	Mt. Ka‘ala	Thorny scrambler	600–1700 m.	Quick recovery though destroyed by fire	Impenetrable thickets expand by rooting of aerial shoots.	None.
Schinus terebinthifolius (Christmas berry)	O‘ahu	Low growing deciduous tree	Most mesic to wet lowland habitats.	Killed by high intensity fire but regenerates rapidly.	Shades out others; allelopathic; spread by pigs and fruit-eating birds.	Bio-control attempted many times, but largely unsuccessful and opposed by beekeepers.

Source: Various

D. Prospective Funding Sources

Source	*Five-Star Restoration Challenge Grants*	*Bring Back the Natives (BBN)*	*Native Plant Conservation Initiative (NPCI)*	*Pulling Together Initiative (PTI)*
Purpose	Support community-based wetland, riparian, and coastal habitat restoration projects that build diverse partnerships and foster local natural resource stewardship through education, outreach, and training activities.	Supports on-the-ground habitat restoration projects that benefit native aquatic species (e.g., native fish, aquatic insects, mollusks, and amphibians) in their historic range.	Supports on-the-ground conservation projects that protect, enhance, and/or restore native plant communities on public and private land.	The goals of PTI are: 1) to prevent, manage, or eradicate invasive and noxious plants through a coordinated program of public/private partnerships; and 2) to increase public awareness of the adverse impacts of invasive and noxious plants.
Eligible Applicants	Projects must involve diverse partnerships of ideally five organizations that contribute funding, land, technical assistance, workforce support, and/or other in-kind services. Deadline: March 1, 2002.	Projects should ideally involve multiple federal, tribal, state, and local governments; corporations; private landowners; communities; and or non-profit groups.	Projects should ideally involve multiple federal, tribal, state, and local governments; corporations; private landowners; communities; and or non-profit groups.	Provides a means for federal agencies to be full partners with state and local agencies, private landowners, and other interested parties in developing long-term weed management projects within the scope of an integrated pest management strategy.
Land Area	Wetland, riparian, and coastal habitats	Must benefit fish, wildlife, and other biotic resources on federal lands or lands that directly benefit federal lands and programs.	Must benefit fish, wildlife, and other biotic resources on federal lands or lands that directly benefit federal lands and programs.	Must benefit fish, wildlife, and other biotic resources on federal lands or lands that directly benefit federal lands and programs.
Funding	In 2001, 60 projects received grants of on average $10,000 (range from $5,000 to $20,000) out of approximately 230 applications.	Require non-federal, third-party funds, in the form of cash and or contributed goods and services (at least a ratio of 2:1 or higher)	Require non-federal, third-party funds, in the form of cash and or contributed goods and services (at least a ratio of 2:1 or higher)	Require non-federal, third-party funds, in the form of cash and or contributed goods and services (at least a ratio of 2:1 or higher)
Source Agency	National Association of Counties, National Fish and Wildlife Foundation, Wildlife Habitat Council, U.S. EPA, NOAA Fisheries	National Fish and Wildlife Foundation (BLM, BOR, FS, and FWS)	National Fish and Wildlife Foundation (BLM, FS, FWS, and NPS)	National Fish and Wildlife Foundation
Contact	http://www.nfwf.org/programs/5star-rfp.htm	Justin Johnson, 202-857-0166 http://www.cotrout.org/BBN/index.html http://www.cotrout.org/files/ngo-rfp_2001.doc	Justin Johnson, 202-857-0166 http://www.nps.gov/plants/nfwf/02rfp.htm	Justin Johnson, 202-857-0166 http://www.nfwf.org/programs/rfp_2002.html

Source	Partners for Fish and Wildlife	Farmland Protection Program	Wildlife Habitat Incentives Program	Environmental Quality Incentives Program	Soil and Water Conservation Fund.
Purpose	Cost-sharing and technical assistance for long-term habitat restoration projects	Protect farmland from conversion to non-agricultural land uses through acquisition of conservation easements or other interests in lands.	Help develop wildlife, wetland wildlife, threatened and endangered species, fish and other types of wildlife habitat.	Voluntary conservation program for farmers and ranchers facing serious threats to soil, water and other natural resources to help install or implement structural, vegetative and management practices.	Address threats to soil, water and related natural resources, including wildlife habitat; Comply with federal and state environmental laws; Make changes to such things as nutrient, pest, or irrigation management, or land uses
Eligible Applicants	Private landowners	States or local governments with a farmland protection program and can provide at least 50% of the easement value.	Landowners with existing or potential wildlife habitat. This program is not currently offered in Hawai‘i, but funding is being requested.	Persons engaged in livestock or agricultural production Landowner of a non-industrial forest.	Private farmers and ranchers
Land Area		Lands with prime, unique or other productive soil, as defined by the Farmland Protection Policy Act.	Program can be used to restore aquatic habitat, stream banks and uplands, but not on converted wetlands.	Eligible lands include cropland, rangeland, pasture, forest lands. Priority areas include wetlands and environ-mentally sensitive areas	
Funding	Funding is limited	$1.3 million in FY 1997. Priority for funding given to offers with at least 50% local funding, lands threatened by conversion, agricultural quality of lands, and environmental considerations.	1996 Farm Bill provides $50 million through year 2002 to implement WHIP nationwide	$200 million per year nationwide through year 2002. Limit of $10,000 per person per year for 5 years	
Source Agency	U.S. Fish and Wildlife Service	U.S. Dept. of Agriculture Natural Resources Conservation Service	U.S. Dept. of Agriculture Natural Resources Conservation Service	U.S. Dept of Agriculture Natural Resources Conservation Service	U.S. Dept. of Agriculture Commodity Credit Corporation
Contact	www.partners.fws.gov Benton Pang, Program Coordinator Ph: 541-3470	NRCS Honolulu Ph: (808) 541-2603	NRCS Honolulu Ph: (808) 541-2603	NRCS Honolulu Ph. (808) 541-2603	Gary Gross, Program Manager NRCS, (gary.gross@usda.gov)

Source	Federal Lands to Parks	Pacific Islands Coastal Program	Candidate Conservation Agreement Grants	Hawai'i Biodiversity Joint Venture	Recovery Land Acquisition Grants
Purpose	Enable state and local governments to establish park and recreation areas and adapt historic buildings for public uses. Federal lands can be acquired at no cost.	A new effort to identify important coastal resource problems and solutions, develop partnerships to carry out on-the-ground conservation projects, and encourage community action in high priority coastal areas.	Support development and implementation of Candidate Conservation Agreements to conserve species before they decline to the point of needing to be listed as threatened species.	Public-private conservation efforts to protect and restore native biological diversity though habitat restoration, restoration techniques development and public outreach.	Acquire habitat for endangered and threatened species in support of approved recovery plans.
Eligible Applicants	Only state and local governments can apply for surplus real property for public park and recreational purposes.		Through the State		Through the State
Land Area	Surplus real property released by the Federal government, including Dept of Defense property transfers from base closures.				
Funding	No costs involved, but applicants must agree to manage the property in the public interest for public park and recreation use.		$5 million		$11 million
Source Agency	U.S. Dept. of Interior National Park Service	U.S. Fish and Wildlife Service	U.S. Fish and Wildlife Service	U.S. Fish and Wildlife Service	U.S. Fish and Wildlife Service
Contact	NPS Federal Lands to Parks Program Ph: (415) 427-1444	www.fws.gov/cep/cepcode.html Chris Swenson, Program Coordinator Ph: 541-3491 chris_swenson@fws.gov	www.endangered.fws.gov/landowner/grants.pdf	Craig Rowland, Cons. Part. Coordinator, Ph: 541-3441 Craig_Rowland@fws.gov	http://pacific.fws.gov

Source	Wetlands Reserve Program	Forest Incentives Program	Forest Legacy Program	NOAA Community-Based Restoration Program	Conservation Reserve Program
Purpose	Voluntary program to restore and protect wetlands on private property.	Plant more trees and place more forestland under good forest management to assure future supplies for sawtimber, pulpwood, and quality hardwoods.	Help landowners Identify and protect environmentally important forestlands threatened by conversion to non-forest uses. Includes protection of important scenic, cultural, fish, wildlife, recreational resources, and riparian areas.	Provides financial assistance and technical expertise to restore marine, estuarine and anadromous fish habitat by addressing address important fishery habitat damage or coastal loss by means of a grass-roots, bottom-up approach.	Encourage farmers to plant long-term resource-conserving covers to improve soil, water and wildlife resources. Offers annual rent payments, incentive payments and cost sharing to establish approved cover on eligible cropland.
Eligible Applicants	Land owner for at least one year prior to enrolling land in program	This program is not available in Hawai‘i at this time.	Landowners or owners of interests in land with forest or ecological values	Organizations such as non-profits, local or state governments and Federal agencies in partnership with others.	Landowner for at least one year of eligible croplands
Land Area	Lands must be restorable and suitable for wildlife	Between 10 to 1,000 acres of forest lands suitable for reforestation or improved forest management	Lands with significant environmental values, or threatened by conversion to non-forest uses.		Cropland planted with agricultural crop for 2 of the 5 most recent crop years, or marginal pasture land suitable for use as riparian buffer
Funding	1995 Wetlands Reserve Program funded at $92 million. Landowner may not be paid more than agricultural value of land.	Federal cost sharing up to 65 percent, with annual limit of $10,000 per person.	Federal government will pay full fair market value for all or part of the ownership rights desired for release by applicant. Cost-sharing with state and local agencies, with 75% maximum Federal share.	$8 million in 2001 has previously funded such activities as weed removal and watershed restoration. RFA postmarked by April 15, 2002.	Up to 50 percent of participant’s costs, with duration of contracts between 10 to 15 years, subject to funding availability.
Source Agency	U.S. Dept of Agriculture Natural Resources Conservation Service	U.S. Dept of Agriculture Natural Resources Conservation Service	U.S. Dept. of Agriculture U.S. Forest Service	National Oceanic and Atmospheric Administration (NOAA) Fisheries	U.S. Dept of Agriculture, Farm Service Agency
Contact	NRCS Honolulu Ph: (808) 541-2603	NRCS Honolulu Ph. (808) 541-2603	USFS, Fred Bell 522-8230, ext. 106 and Sandy Stone, (707) 562-8918; Hawai‘i DLNR, DoFAW	NOAA, Robin Bruckner (301) 713-0174 or Robin.Bruckner@noaa.gov	State Executive Director Ph. (808) 541-2644

Source	Natural Area Partnership Program	Nonpoint Source Pollution Management Program	Hawai'i Clean Water State Revolving Funds (CWSRF)	Watershed Assistance Grants
Purpose	Support for management of natural resources on private lands permanently dedicated to conservation. Used for management plans and activities to protect, restore, or enhance significant native resources or geologic features.	Heighten public awareness of nonpoint source pollution issues and provide technical and financial assistance to applicants who wish to implement a nonpoint source pollution management program.	Created by Clean Water Act, the CWSRF acts as community bank to provides low-interest loans to Counties to protect water quality and public health while building Hawaii's economy	A highly competitive, national grant program to support the growth and sustainability (i.e., organizational capacity) of local watershed partnerships in the United States.
Eligible Applicants	Landowner or non-profit private cooperating entity, watershed partnerships	State and county agencies and private groups who prepare a management plan in conjunction with a public agency.	Available only to state or county agencies	Local watershed partnerships
Land Area	Lands must be of "natural area quality", with intact native Hawaiian ecosystems, habitat for endangered species, or within the Conservation District "Protective" subzone	No minimum or maximum land area currently specified		United States
Funding	State matching funds on 2:1 basis. Approximately $1 million per year. For Fiscal Year 2001, emphasis on watershed partnership funding. Examples of projects to be funded: watershed management plan implementation; monitoring effects of watershed protection; road and trail maintenance; community outreach programs	Total funding for the Nonpoint Source Pollution Management Program in Hawai'i is $400,000. Grantees must provide a 100% match of funds received. 2002 priority for incremental sec. 319 funds on impaired waters needing TMDLs.	Can fund anything within the State's NPS Pollution Plan. Projected pollution control needs for the state are over $1 billion.	Grants of up to $30,000 are available to partnerships meeting stated criteria. At this time, there are no funds for WAG 2002.
Source Agency	State of Hawai'i Department of Land and Natural Resources, Division of Forestry and Wildlife	State of Hawai'i, Department of Health, Clean Water Branch	State of Hawai'i, Department of Health, Clean Water Branch	EPA, through a cooperative agreement with River Network.
Contact	Betsy Gagne, DLNR Ph. (808) 587-0063	Lawana Collier or Colin Tanaka Ph: (808) 586-4309/4345 www.state.hi.us/doh/eh/cwb/prc/index/html	Lawana Collier or Colin Tanaka Ph: (808) 586-4309/4345	http://www.rivernetwork.org/howwecanhelp/howwag.cfm#wag

Source	Habitat Conservation Plan Grants	Safe Harbor Grants	The Science to Achieve Results (STAR) Program	Federal Stewardship Incentive Program and Hawai'i State Forest Stewardship Program	National Fish and Wildlife Foundation Coral Reef Conservation Projects
Purpose	Support the development of Habitat Conservation Plans, which allow landowners to harm or kill individual members of listed species in the course of legal activities in exchange for taking conservation measures to insure the long-term conservation of the species.	Support development and implementation of Safe Harbor Agreements for listed species on non-federal lands by providing incentives for landowners to manage their property to benefit and attract listed species.	Invite research proposals address a variety of environmental research topics.	Implement management practices to enhance and protect the timber productivity, wildlife habitat, water quality, recreational values or aesthetics of forest properties for a ten-year period. State FSP intended to assist landowners.	Reduce and prevent degradation of corral reefs and associated reef habitats. Projects should address: conservation and management; restoration; outreach, education, training; or applied research. RFA due April 3.
Eligible Applicants	Through the State	Through the State	Academic and non-profit institutions located in the U.S., and state and local governments	Owners of non-industrial private forest lands. Small landowners with lesser quality lands that are not eligible for the NAP program.	U.S. or international non-profit organization, academic institutions, and U.S. Government agencies (local, state, territorial or federal).
Land Area			Any	At least 5 contiguous acres of forested or formerly forested lands	Projects may address causes of coral reef degradation wherever they occur, including inland areas.
Funding	$7 million; HCP Land Acquisition Program - $68 million	$5 million	Funding levels vary ($75K - $500K) yearly, depending on research area. Solicitation periods: January, April, August, and October.	Provides matching State funds on a 1:1 basis with private funds. Funding shared w/ NAPP. About $500,000 in annual funding.	Most grants between $10K-$50K. Average ~$25K. Minimum non-federal matching of 1:1 required. 2:1 matching preferred.
Source Agency	U.S. Fish and Wildlife Service	U.S. Fish and Wildlife Service	USEPA's National Center for Environmental Research	U.S. Forest Service and State Dept. of Land and Natural Resources, Division of Forestry and Wildlife	National Fish and Wildlife Foundation, in partnership with NOAA.
Contact	http://pacific.fws.gov	www.partners.fws.gov Benton Pang, Program Coordinator, Ph: 541-3470	http://es.epa.gov/ncer/rfa/	Nelson Ayers, DLNR Ph. (808) 587-4175	http://www.nfwf.org Michelle Pico (pico@nfwf.org).

E. Current Project Management and Community Efforts

The following organizations and community groups, alphabetically listed, have conducted a variety of activities in the greater Koʻolau watershed area. Although most of these projects have been confined to the *makai* portions of the watershed, their activities, knowledge and connections can serve as valuable resources. The organizations can provide an inroad to potential joint projects for an *ahupuaʻa*-type management of the Koʻolau Mountains.

ʻAikahi Elementary School
Doing water quality monitoring

Ala Wai Watershed Group
The Ala Wai Watershed Group, primarily EPA-funded, is a community-based organization emphasizing community and student assistance and participation in resource management and monitoring. The goal of the group is to improve the water quality within the Ala Wai Watershed. Current and future projects consist of:

- Stream and stream bank clean up of Makiki, Mānoa and Pālolo Streams
- Restoring stream banks with native vegetation
- Monitoring heavy metals in storm drain run-off
- Promoting educational programs, such as *loʻi* building and taro farming
- Reducing trash dumping along Tantalus by building barricades

Contact: Karen Ah Mai, Executive Director
awed@alawaiwatershed.org
Ala Wai Watershed Association
1833 Kalakaua Ave., Suite 905
Honolulu, HI 96815
808-955-7882.

Center for a Sustainable Future
The Center for a Sustainable Future is designed as a private institution, closely affiliated with scientists in the University of Hawaiʻi, with the goal of bringing together scientists, engineers, and economists to address long-range technological issues arising from the need to achieve sustainable development. Our focus will be on Hawaiʻi, the tropical Pacific and the Pacific Rim. The Center for a Sustainable Future will see to the integration of new scientific research and development with the economic and policy studies required for implementation.

Contact: C. Barry Raleigh, President
raleigh@soest.hawaii.edu
Website: http://www.soest.hawaii.edu/csf/

The Friends of Haʻikū Stairs (FHS)
Friend of Haʻikū Stairs is a 501(c)(3) non-profit organization that works closely with the City and the Department of Hawaiian Homelands and encourages inter-organizational cooperation toward the common goal of repairing and re-opening the Stairs. The organization was formed by Frank Stong, Suzanne Hieb, and John Flanigan after the Stairs' initial closing in June 1987

in an attempt to organize popular support to encourage the transfer of the Stairs to the City or State and to reopen them to hikers. This effort gained much popular and official support, but was thwarted when the area was closed for construction of the H3 highway. Upon the completion of the H3 and the closing of the Omega station in 1999, the effort has been renewed. Another organization–the Koʻolau Foundation–is formulating a plan to convert the Omega Station site and valley into a recreation and cultural preserve, with traditional Hawaiian medicinal plants and practices and a museum of Windward cultural artifacts.

Contact: John Flanigan, johnf@hawaii.edu
P.O. Box 4715
Kaneohe, HI 96744
Website: http://www.friendsofhaikustairs.org/

ʻIlioʻulaokalani
A coalition of traditional Hawaiian cultural practitioners, founded by Vicky Holt Takamine, the organization works to strengthen the Hawaiian community in their fight to preserve and protect their native gathering rights, cultural traditions and natural resources.

Kahawai Ola
Kahawai Ola monitors stations in areas of varied land use (forest, residential, wetland, estuarine) on Haʻikū and Heʻeia streams on the windward side of Oʻahu. They also monitor the input of stream-derived nutrients and sediments into a coral reef ecosystem.

Contact: Scott Larned
P.O. Box 1346, Kaneohe, Hawaiʻi 96744
Phone: 808 236-7440, email: slarned@hawaii.edu

Kailua Bay Advisory Council
The Kailua Bay Advisory Council (KBAC) was created by consent decree as the result of a lawsuit brought against the City and County of Honolulu by several windward Oahu environmental organizations. The organizations are Save Our Bays and Beaches; Hawaii's Thousand Friends; the Sierra Club; and the Surfrider Foundation. KBAC aims to "Empower the Community for Improved Water Quality in Koʻolaupoko". The Council is a community-based group focused on establishing a volunteer water quality monitoring program. The main goal is to engage volunteers in community activities keeping streams and waters clean, and to develop public education programs for pollution prevention.

Website: http://www.kbac-hi.org/
45-270 William Henry Road, Room 201-4, Kaneohe, HI 96744
Ph: (808)234-0702 FAX: (808)234-0645
Maile Bay, Director
Ph: 808.225.9210, or 808.263.1927 / fax: 808.262.8175
mbay@hawaii.rr.com, bay@hula.net, kbac-vc@hawaii.rr.com

Kalāheo Environmental Science Class Stream Team
Kalāheo Environmental Science Class' program is designed to establish baseline data on Kailua watershed from its top to the ocean. Students are the main work force.

Contact person: Barbara Volhein,
Kalāheo High School 730 Iliaina St., Kailua, Hawai'i 96734
Phone: 808 854-7900

Kawai Nui Heritage Foundation
The Kawai Nui Heritage Foundation is a non-profit organization striving to protect the natural wetland, flood control, wildlife, and cultural values of the marsh. The Foundation's purpose is to educate the public about the inherent natural, educational, recreational, agricultural, historical and cultural resources within the Kailua watershed (*ahupua'a*). The Foundation proposes to preserve the integrity of these resources by implementation of the foundation's directional plan, which is to preserve and maintain Kawai Nui's heritage.

Website: http://www.aloha.net/~cburrow/

Maunalaha Community Association (MCA)
The Maunalaha Community Association is also a newly formed organization focused on establishing Maunalaha Watershed Project. Their mission and overall objectives are currently being formalized. However, MCA identifies three main goals: 1) to develop a Maunalaha Watershed master plan. 2) to establish 3 pilot projects areas for stream bank restoration, *lo'i* construction, and protection of forest resources and 3) to create partnerships with DoFAW, Hawai'i Nature Center, and DLNR.

Pono Pacific Land Management
Pono Pacific was created to assist both the public and private sectors in restoring and protecting our natural resources. Established in 2000, Pono Pacific provides landowners and conservation managers with an effective means to outsource natural resource management projects. The have experience working on a wide variety of conservation projects including trail maintenance, invasive species control, predator control, and coordinating the State Youth Conservation Corps Program.

Contact: John Leong
(808) 595-9095
john@ponopacific.com.
Pono Pacific website: http://www.ponopacific.com

Waimānalo Health Center
The Waimānalo Health Center is a community-based non-profit corporation dedicated to improving the quality of life for the people of Hawai'i by providing ready access to primary and preventive holistic health services. They have conducted stream clean-ups and restoration and are in the process of writing a watershed management plan for Waimānalo.

Contact: Michelle Roper
Ph:259-7948 ext. 145

Waiāhole Water System
Contact: Vernon Pico
99-941 Halawa Valley St., Aiea, HI 96701
Ph: (808)483-7169 Fax: (808)483-7170
Email: waiahole96701@yahoo.com

West Honolulu Watershed Study
The intent of the West Honolulu Watershed Study (watershed analysis) is to assist decision makers in taking a comprehensive look at water resource problems, coordinate and prioritize remedies and solutions, and determine what programs exist that may be utilized in the implementation of solutions. Of particular interest are water resource problem areas and sources of contaminants that impact surface and ground water quality, flood control, ecosystems, and ground water recharge. The West Honolulu Watershed, consisting of Nu‘uanu, Kalihi, and Moanalua drainages, has been determined to contain elevated levels of metals, pesticides, nutrient, and sediment loading problems.

This jointly funded study is being conducted under the Corps of Engineers Planning Assistance to States Program and sponsored by the State Department of Land and Natural Resources (DLNR) and Honolulu Board of Water Supply (BWS). The Study is a watershed analysis that will identify water resource problems, conceptualize solutions, categorize projects by responsible agencies, and determine available project implementation vehicles. The watershed analysis will involve the community to a great extent. The consultant Townscape, Inc., under the direction of the Corps’ Project Manager, is conducting the Study. The results of the Study may coordinate and prioritize implementation and construction actions of relevant agencies for corrective work; this is thought to be beneficial to all agencies and organizations having responsibilities and interest in the watershed.

Contact: Derek Chow, Corps of Engineers’ Project Manager, 438-7009; Carty Chang, Planning Section, DLNR, 587-0273; Scot Muraoka, Environmental Unit, BWS, 527-5221.

KOOLAU MOUNTAINS WATERSHED PARTNERSHIP
MEMORANDUM OF UNDERSTANDING

***THIS MEMORANDUM OF UNDERSTANDING**, made by and between participating major landowners or lessees, i.e. owning or leasing 100 acres or more, herein known as the **"KOOLAU MOUNTAINS WATERSHED PARTNERSHIP" (KMWP)** and hereinafter called the **"PARTNERS"**, agree to participate in cooperative management activities of the Koolau watershed.*

***WHEREAS**, the Koolau forests are a primary water resource for the island of Oahu; and*

***WHEREAS**, active management is needed to maintain a healthy forested watershed to sustain the future quality and quantity of Oahu's water supply; and*

***WHEREAS**, active management of these forested watersheds would also benefit Hawaii's native flora and fauna; and*

***WHEREAS**, active management of the Koolau watershed is also important to the programs of each of the **PARTNERS**; and*

***WHEREAS**, many of the lands managed by the **PARTNERS** share common boundaries (see Exhibit A); and*

***WHEREAS**, many of the threats to the forested watershed, such as feral ungulates, fire, insects, diseases, and invasive non-native plants, occur across these common boundaries; and*

***WHEREAS**, significant economic and staffing advantages will accrue to the **PARTNERS**, if the management of these threats is shared; and*

***WHEREAS**, effective management is best achieved through the coordinated actions of all major landowners in the watershed.*

***NOW, THEREFORE**, the **PARTNERS** hereby agree in principle as follows:*

1. *To develop jointly, a Koolau watershed management plan, to be reviewed annually as needed, that will document Koolau values and identify priority watershed management activities.*

2. *To consider jointly, at such places and at such intervals as may be mutually agreed upon by the **PARTNERS**, general programs and management of projects for the Koolau watershed.*

3. *To determine costs of watershed management programs and projects agreed upon in #2, and join in cooperative efforts to raise outside funds for those projects.*

4. *To develop and implement specific agreements and working plans for individual projects considered by all or some of the **PARTNERS** having mutual interests. Such agreements and working plans may be developed whenever appropriate.*

5. *To enter into specific agreements between all or some of the **PARTNERS**, as the occasion demands, for the use of specialized equipment, hiring and supervision of personnel, transfer of funds, purchasing of supplies, and other matters pertaining to the general purposes of management agreed upon by all or some of the **PARTNERS**. Expenditures under this **Memorandum of Understanding** will be determined by specific working agreements entered into under authority of this instrument contingent upon compliance with applicable laws or policy guidelines which govern such expenditures.*

6. *That other landowner(s) or lessee(s) may enter into this partnership at any time by way of an addendum to this **Memorandum of Understanding**.*

7. *That, for any reason whatsoever, any partner may terminate involvement in this **Memorandum of Understanding** by providing 90 days prior written notice to the other **PARTNERS**.*

***IN WITNESS WHEREOF**, the **PARTNERS** hereto have executed this **Memorandum of Understanding** by way of participant signature and date below.*

Department of Land & Natural Resources

By Timothy E. Johns

Date 8-4-99

Honolulu Board of Water Supply

By _____

Date 8-4-99

Waiahole Water System

By _____

Date 8/4/99

Kamehameha Schools Bishop Estate

By _____

Date 8-4-99

The Queen Emma Foundation

By _____

Date 08/04/99

United States Army

By _____

Date 8/04/99

Department of Hawaiian Home Lands

By _____

Date 8/4/99

Bishop Museum
(Affiliation)

By Patrick J. Duarte

Date 8-4-99

Diana Pantaleo
(Affiliation)

By Laura Thornton

Date 11/19/99

Manana Valley Farm LLC
(Affiliation)

By Douglas Smith

Date 11/19/99

Dole Food Company
(Affiliation)

By J. D. Kinney

Date 11/19/99

U.S. Fish & Wildlife Service
(Affiliation)

By Donna J. Stovall

Date 3-28-2001

_____
(Affiliation)

By _____

Date _____

_____
(Affiliation)

By _____

Date _____

_____
(Affiliation)

By _____

Date _____

G. Selected Hawai‘i Revised Statutes and Administrative Rules

HAWAII ADMINISTRATIVE RULES
TITLE 13
Subtitle 1

Chapter 5 Administration: Conservation District.

Subtitle 5

Part 1 Chapter 104: Rules regulating activities within forest reserves
Chapter 105 Rules regulating restricted watersheds
Chapter 107: Rules regulating the use of threatened and endangered plants
Part 2 Chapter 121: Rules regulating the hunting of wildlife on public lands and other lands
Chapter 122: Rules regulating game bird hunting, field trials and commercial shooting preserves
Chapter 123: Rules regulating game mammal hunting
Chapter 124: Rules pertaining to indigenous, endangered, threatened and injurious wildlife, and introduced wild birds
Chapter 125: Rules regulating wildlife sanctuaries
Part 3 Chapter 130: Rules for Hawai‘i statewide trail and access program (Nā Ala Hele Program)

Subtitle 6

Chapter 146 Hawai‘i State Park System.
Chapter 6E Historic Preservation

Subtitle 7

Chapter 167: Rules of Practice and Procedure for the Commission on Water Resource Management
Chapter 168: Water Use, Wells, and Stream Diversion Works
Amendment 68-14: Well Construction and Pump Installation Standards
Chapter 169: Protection of Instream Uses of Water
Chapter 170: Hawai‘i Water Plan
Chapter 171: Designation and Regulation of Water Management Areas
Amendments Sections 171-60 to 171-62: Reservations of Water, Dept. of Hawaiian Home Lands reservations for Honolulu and Leeward Oahu, Dept. of Hawaiian Home Lands reservation for Windward Oahu
Chapter 172: Hawaiian Water Rights
Chapter 190: Water and Land Development: Dams and reservoirs.

Subtitle 8

Chapter 197: Hawai‘i Historic Places Review Board
Chapter 198, Hawai‘i and National Register of Historic Places Programs

Subtitle 9

Chapter 208: Rules of practice and procedure for the Natural Area Reserves System (NARS) Commission

Chapter 209: Rules regulating activities within Natural Area Reserves. Includes permitted activities, prohibited activities, and special use permits, and penalties

Subtitle 10

Chapter 221: Land Management: Unencumbered Public Lands.

Subtitle 13

Chapter 300 Rules of Practice and Procedure Relating to Burial Sites and Human Remains

Chapter 198	Conservation Easements
Section 205-17	Land Use Commission Decision-making Criteria
Section 205A-2	Coastal Zone Management Program; Objectives and Policies
Section 226-12	Objectives and Policies for the Physical Environment – Scenic, Natural Beauty, and Historic Resources
Section 343-5	Environmental Impact Statements, Applicability and Requirements

TITLE 28, Chapter 520 Landowners Liability

Act 152, SLH 200 (HB2835, HD2, SD2, CD1) Relating to Watershed Protection